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CONTENTS

CHAP. PAGE
I. INTRODUCTION 1
II. GENERAL RULES FOR PIPES 5
III. WOOD PIPES 16
IV. CAST-IRON PIPES 24
V. CAST-IRON BALL-AND-SOCKET PIPES . . 40
VI. GENERAL REMARKS ON CAST-IRON PIPES, AND RULES AND FORMULÆ RELATING TO THEM 45
VII. WROUGHT-IRON, STEEL, COPPER, AND BRASS PIPES 51
VIII. REMARKS ON WROUGHT-IRON PIPES . . 86
IX. LEAD AND COMPOSITION PIPES . . 90
X. EARTHENWARE, STONEWARE, STONE, GLASS, AND CEMENT PIPES 98
XI. SWIVEL PIPE JOINTS 127
XII. SUNDRY PIPE JOINTS 133
XIII. CORROSION AND DELETERIOUS EFFECT OF WATER IN PIPES 135
XIV. TESTING PIPES 153
XV. LAYING OF PIPES 160
XVI. DRILLING AND RIVETING MACHINES FOR PIPES 175
XVII. TABLES 186
INDEX 235

PIPES AND TUBES

CHAPTER I

INTRODUCTION

PIPES, whether we consider their diversity of form and material, or the almost infinite variety of purposes to which they are applied, certainly possess an inherent interest of their own. As they also represent the investment and the constant outlay of vast sums of money, they assume considerable importance even when regarded from a purely commercial standpoint. Moreover, their manufacture and employment frequently present difficult problems for solution by engineers, builders and artisans. Every one connected with engineering and building trade is constantly and more or less directly concerned with the manipulation of pipes.

Want of knowledge upon the subject gives rise to a great deal of unnecessary expense. Money is wasted upon pipes that are too large and too heavy; or, on the other hand, extra expense is incurred because the pipes are found to be too small. Again, pipes are often made of material unsuitable for the purpose to which they are applied, or they are not properly protected from rust, from the weight of the traffic on the roads, or from frost.

To show the various uses to which pipes are put, the following list of underground pipes employed in the large cities in the United States of America is given below:—

1. Pipes for conveying and delivering illuminating gas.
2. For conveying and delivering fuel gas.
3. For conveying salt water for street sprinkling and for fire extinction.
4. For draining and carrying off sewage and surface water.
5. For conveying and delivering drinking water.
6. For delivering hot water under high-pressure for heating purposes and power.
7. For delivering cold water under high-pressure for power.
8. For delivering live steam under pressure for heating purposes and power.
9. For delivering compressed air for purposes of power and ventilation.
10. For producing power where required by vacuum or suction, and for ventilation.
11. For conveying letters and packages by compressed air or by vacuum.
12. For regulating clocks by compressed air.
13. For electrical wires for electric lighting, electric railways, telephones and telegraphy.
14. For conveying mineral oils.

15. For power ropes for driving machinery, moving street railway cars, etc.

This list could no doubt be considerably extended, but it is already sufficient to show the scope of the subject.

The ancients, as far as we know, used very few pipes, they generally made culverts of brick or cement. They sometimes used lead pipes, but of a very small diameter only, because on account of the imperfect machinery in which they were made, they could not resist any great strain.

The early Egyptians seem to have been well acquainted with hydraulic principle, and that the Romans were not destitute of similar knowledge is proved by the discovery, for instance, of lead pipes supposed to have been used in the baths at Caracalla; while Pliny plainly asserts that "water will ascend to the height of its source," therefore the statement given by some authors that the ancients were ignorant of the rudimentary fact that water will rise to a level in opposite branches of a pipe-main, is incorrect; Pliny finishes his sentence with: "in order to raise water up to an eminence, leaden pipes must be employed."

Rev. W. M. Thompson, D.D., in his well-known interesting work, *The Land and the Book*, in describing the waterworks at Sidon, says:—"As there are no traces of arches up to the city, it has been conjectured that the Sidonian engineers were acquainted at that early age with the principle of hydrostatics that water will rise to the level of its source. People also tell me that fragments of earthenware pipes incased in lead have been dug up in the gardens in a probable line of these canals. These may have served to conduct the water to the city. . . . Everything about them bears witness to their extreme age."

Owing to the primitive condition of the manufacturing arts, however, the Romans and Egyptians were unable to give effect to their knowledge. Their employment of aqueducts and large culverts was due to the fact that they were unable to bring the aforementioned principle into play simply because they lacked the means of producing or uniting lead pipes of the size and strength required for the enormous quantities of water used in Rome, lead being at that time the only material that could be employed. Moreover they were well acquainted with the tendency of lead to poison the water.

CHAPTER II

GENERAL RULES FOR PIPES

WATER PIPES

WHEN the diameter and the length of the pipes are constant, the discharge varies directly as the square root of the head; therefore, if it is required to double the discharge of a pipe, keeping the diameter and the length the same, the head must be increased four times.

When the head and the length are constant, the discharge varies directly as the square root of the fifth-power of the diameter; therefore, in the case of two pipes having the same head and length, but with diameters of 3 inches and 4 inches respectively, the discharge will be as the square root of the fifth-power of these diameters, or as 15·59 is to 32·0; or, everything being equal, a 4-inch pipe will discharge double the quantity passed by a 3-inch pipe.

When the discharge and length are constant, the head will be inversely as the fifth-power of the diameter; therefore, for diameters in the ratio of 1, 2 and 4, the head will be in the ratio of the fifth-power of 4, 2 and 1.

When the head and diameter are constant, the discharge will be inversely as the square root of the length; therefore, the lengths in the ratio of 1, 2 and 4, the discharge will be as the square root of 4, 2 and 1.

When the discharge and diameter are constant, the head is as the length; therefore, in the ratio of 1, 2 and 4, the heads will also be 1, 2 and 4.

To find the Velocity of Water in Pipes.

The general law for the discharge of any pipe is proportional to the square root of the head, and, conversely, the head is proportional to the square of the discharge.

The formula is therefore :—

$$V = 8 \times \sqrt{H};$$

in which V = the velocity of discharge at the point of greatest contraction in feet per second;

H = head on the centre of the pipe in feet;

and the quantity of water discharged for the reduced area at the point of greatest contraction; however, the following rule :—

$$G = \sqrt{H} \times d^2 \times 16{\cdot}3$$

is correct enough for any practical purpose;

in which G = gallons delivered per minute;

d = diameter of pipe in inches;

H = head of water in feet;

or *Jackson's Rule*—

$$V = C \times 100\sqrt{RS};$$

in which V = velocity of discharge in feet per second;

C = 1·054 for new cast-iron pipes;

= 0·765 for old cast-iron pipes;

= 0·765 for wrought-iron pipes;

R = mean radius of pipe in feet;

S = slope.

To find Friction of Water in Pipes.

The late Mr. Thomas Box, in his valuable little book, *Practical Hydraulics*, says:—"When a pipe discharging water is of a considerable length there is a loss of head due simply by the friction of the water against the side of the pipe, so that in all cases the head consumed may be considered as composed of two portions: one the amount due to the velocity of entry irrespective of friction, and the other the amount due to friction alone, irrespective of the amount due to velocity. In long mains the amount of head due to the velocity of entry is so small a proportion of that due to friction that it may be neglected without sensible error, but in short pipes it may be much greater than the head due to friction, and therefore in such cases it cannot of course be neglected."

The friction of water in small pipes is very great, but is reduced as the diameter is increased and the quantity decreased.

The loss of head due to friction in pipes may be calculated by the rules:—

$$G = \sqrt{\frac{(3d)^5 \times H}{L}}; \quad H = \frac{G^2 \times L}{(3\,d)^5};$$

$$d = \sqrt[5]{\frac{G^2 \times L}{H}} \div 3; \quad L = \frac{(3\,d)^5 \times H}{G^2};$$

in which d = diameter of pipe in inches;

L = length of pipe in yards;

H = head of water in feet;

G = gallons of water passing through the pipe in one minute.

These formulæ are easiest calculated by logarithms in the following manner:—

$$\frac{5 \times \log. 3d + \log. H - \log. L}{2} = \log. G.$$

The loss of head due to friction in bends may be calculated by the rule:—

$$H = 0{\cdot}0155\ V^2 \left(\frac{A}{180} \times C\right);$$

in which H = head of water in feet;
V = velocity of water in feet per second;
A = the angle of bend with forward line of direction in degrees;
C = a coefficient.

The value of C when the ratio of the radius of the centre line of bend to the radius of the bore are:—

0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
0·131	0·138	0·158	0·206	0·294	0·44	0·66	0·98	1·4	2·0

Diameter of Pipe required.

Mr. Hawksley's method of ascertaining the diameter to be given to the pipes laid down upon what is called the constant delivery system—in which the pipes are always under charge, and no cisterns are used—is to divide the length of the main in a street into portions of 200 yards each, and to assign to every such portion the quantity of water it would be likely to require, on the supposition that that quantity would be discharged in four hours. He then allows for a loss equal to 4 feet in every 200 yards, and adopts, in calculating the diameter to be given, the formula:—

$$d = \frac{1}{15}\sqrt[5]{\frac{G^2 \times L}{H}};$$

in which G = the number of gallons per hour;
L = the length of the pipe in yards;
H = the head in feet;
d = the diameter of pipe required in inches.

To find the Inclination of Pipes in feet per mile to be overcome by Friction.

$$I = \frac{V^2 \times 2{\cdot}3}{D};$$

in which I = inclination of pipe in feet per mile;
V = velocity in feet per second;
D = diameter of pipe in inches.

Usual Inclinations of Pipes.

1 inch in 12 feet = minimum fall for house drains;
1 " 16 " = " " land drains;
1 " 40 " = " " sub-main drains for houses;
1 " 100 " = " " main drains for houses;
1 " 480 " = " " supply pipes for reservoirs.

Discharge through Pipes.

Discharge in 24 ÷ 1440 = discharge per minute;
" cubic feet per minute × 9000 = gallons per day, 24 hours;
" " " second × 2·2 = cubic yards per minute;

Discharge in cubic feet per second × 6·24 = gallons per second;
" " " " × 133 = cubic yards per hour;
" " " " × 375 = gallons per minute;
" " " " × 2400 = tons per day of 24 hours;
Velocity in feet per second × 0·68 = miles per hour;
" " " × 60 = feet per minute;
" " " × 20 = yards per minute;

Pressure head of water in feet = pressure of water in lbs. per square foot × 0·016;

Pressure of water in lbs. per square foot = head in feet × 62·32.

To find how many Pipes it will take to discharge the same quantity as one large Pipe.

$$N = \frac{\sqrt{D^5}}{\sqrt{d^5}};$$

in which N = number of small pipes;
D = diameter of large pipe in inches;
d = diameter of small pipes in inches.

STEAM PIPES.

To find the Flow of Steam in Pipes.

(Babcock's Rule.)

$$W = 300\,\frac{D\,(P-p)\,d^5}{L\left(1+\dfrac{3{\cdot}6}{d}\right)}$$

in which W = weight of steam in lbs.;
d = diameter of pipe in inches;
D = density or weight per cubic foot of steam in lbs.;
P = initial pressure in lbs. per square inch;
p = pressure at end of pipe in lbs. per square inch;
L = length of pipe in feet.

The loss of head due to generation of the velocity of flow, and the friction of the steam entering the pipe, is about equal to the resistance of a length of pipe equal to the quotient of 114 diameters, divided by $\left(1 + \frac{3 \cdot 6}{d}\right)$, in which d = the diameter of pipe in inches.

To find the Diameter of Steam Pipe.

$$D_1 = \sqrt{\frac{D^2 \times P}{8000}};$$

in which D_1 = diameter of steam pipe in inches;
D = diameter of steam cylinder;
P = piston speed in feet per minute.

$$D_1 = \sqrt{D_{11}{}^2 \times 2};$$

when D_{11} = diameter of branch steam pipe in inches, when two cylinders have to be supplied from the main steam pipe.

Loss due to Condensation in Long Steam Pipes.

Some tests were carried out by Mr. Henry Davey on a 7½ inches diameter steam pipe, 1 inch thick and 1100 feet long, conveying steam at a pressure of 45 lbs. per square inch to an underground pumping engine in the Morton Pit at Clay Cross, the pipes being covered with a non-conducting material. As the result of careful observation it was found that the condensation of steam in the pipe amounted to 500 lbs. per hour when the engine was standing, and 750 lbs. per hour when the engine was working, equivalent to 0·183 and 0·274 lb. per square foot of surface of pipe per hour respectively.

In another experiment, carried out by Mr. W. W. Beaumont at the Staveley Hill Colliery, it was found that in a total length of 2300 feet, 1900 feet of which was underground and covered in some instances to a depth of 2 feet with rough stuff left after cutting away the coal, the condensation in a 6½ inches pipe, 1⅛ inches thick, conveying steam at an average pressure of 34 lbs. per square inch, was 600 lbs. per hour with the engine standing and 1400 lbs. per hour with the engine at work, equivalent respectively to a condensation of 0·113 and 0·265 lb. per square foot of surface of pipe per hour.

AIR PIPES.

To find Velocity of Air in Pipes.

$$V = 396\sqrt{\frac{H \times D}{L}};$$

$$H = \frac{L \times V^2}{156{,}800 \times D};$$

in which V = velocity of air in feet per second;
H = head or drag in inches of water;
D = diameter of pipe in feet;
L = length of pipe in feet.

To find Head due to Friction in Air Pipes.

$$H = \frac{C^2 \times L}{(3{\cdot}7\,D)^5};$$

$$C = \sqrt{\frac{(3{\cdot}7\,D)^5 \times H}{L}};$$

$$(3{\cdot}7\,D)^5 = \frac{C^2 \times L}{H};$$

$$L = \frac{(3{\cdot}7\,D)^5}{C^2} \times H.$$

When H = the head, or difference of pressure at the two ends of the pipe, in inches of water;
C = cubic feet of air per minute;
L = length of pipe in yards;
D = diameter of pipe in inches.

Flow of Gas in Pipes.

$$Q = 1350\,D^2\sqrt{\frac{H \times D}{G \times L}};$$

Coal gas, specific gravity 0·42 = $Q = 2100\,D^2\sqrt{\frac{H \times D}{L}}$;

Water gas, specific gravity 0·60 to 0·70 =

$$Q = 1675\;D^2\sqrt{\frac{H \times D}{L}};$$

$$D = 0{\cdot}056\,\sqrt[5]{\frac{Q^2 \times G \times L}{H}}.$$

When Q = quantity of gas in cubic feet per hour;
L = length of pipe in yards;
D = diameter of pipe in inches;
H = head of water pressure in inches;
G = specific gravity of the gas.

HEATING ROOMS BY STEAM AT 212° FAHR.

To find the length in feet of Steam Pipe.

$$L = \frac{F \times (T - t)}{C};$$

in which L = length of pipe in feet;
F = cubic feet of air to be warmed per minute;
T = temperature of the air in the room in degrees Fahr.;
t = external temperature in degrees Fahr.;
C = a coefficient = 304 for 4-inch pipe;
= 228 for 3-inch pipe;
= 152 for 2-inch pipe;
= 76 for 1-inch pipe.

To find Quantity of Air to be heated per minute.

F = 4 to 5 cubic feet for each person;
= 1¼ cubic feet for each square foot of glass in conservatories and hot-houses;
= for wood frames, deducting ⅛ from the gross area of surface.

HEATING BUILDINGS WITH HOT WATER.

To find the length of Hot-water Pipes.

In churches and very large public buildings having only an average number of doors and windows.

$$L = \frac{F}{200};$$

in which L = length of hot-water pipes, 4 inches diameter, which will be required, in feet, to obtain a temperature of about 55 to 58° Fahr.;
F = cubic measurement of the room in cubic feet.

For smaller rooms, dwelling-houses, etc.

$$L = \frac{F}{150}.$$

If 3-inch pipes are used, multiply the quotient so obtained by 1·33, and if 2-inch pipes by 2.

CHAPTER III

WOOD PIPES

THE first patent in England relating to wood pipes was Patent No. 9, secured by one Robert Crumpe, and dated 1618. The title of Crump's specification is :—" Pumps for draining mines, raising water for the service of towns, castles, etc.," and it is therein claimed that the invention is " furre different and exceeding all engines, instruments, or devices theretofore founde oute and used in or about the premices (that is to say) by a certeine hollow trunk or pipe of one entire length, to be made of tymber or leade, which is to reach from the water that is to be drawne or raysed into the toppe or place where the same water shall be to uent or yssue forth, att the foote of which saide trunck or pipe so made of entyre length as aforesaid, and in some other parts or places thereof, there are to be placed and fuxed cteine suckers, drawers, or other device." There is no description of the manner in which these trunks or pipes were made, nor of how the various lengths were joined together.

There can be no doubt that wood pipes date back to a very early period, and the most natural form that suggested itself was obtained by simply nailing four planks together so as to form a square or rectangular section. Of course such primitive pipes were incapable of withstanding much pressure, and so they were in time improved by boring out logs of wood strengthened by means of wrought-iron hoops or straps. It is, no doubt, owing to this early practice, that the rising-mains in pit and mine shafts are still termed "pump-trees." Pipes of the latter description were used in the tin mines in Cornwall at a very early period.

A few months ago the author had the pleasure of seeing some pipes of this description in the Strand, London, that had been dug up there that day.

The pipes used for the first waterworks at Bethlehem, in Pennsylvania, were bored-out logs of hemlock. At the same place, in 1762, the force-mains were of gum-wood and the distributing pipes of pitch-pine. The latter had to be removed in 1769. In the year 1786 lead pipes were substituted for the gum-wood force-mains, as well as for most of the distributing pipes. The last pitch-pine pipes were abandoned in the year 1791.

Whilst wood pipes were being thus superseded in America it might appear that in England they were still regarded with favour, for we find that in the year 1796 Mr. John Howett secured a patent for a machine for boring logs of wood, and the Cornishmen were busy making wood pipes for their pumps in the year 1792.

Sheffield secured an Act of Parliament sanctioning new waterworks in the year 1830; up to that time the whole of the water supply had been conducted through wood pipes fashioned out of the trunks of oak trees. These trunks measured 9 to 12 inches in diameter, and were made tubular by holes from 3 to 6 inches diameter being bored through the cores or centres. This mode, however, was inadequate for the purpose, the wood was liable to early decay, and its first cost exceeded that of cast-iron, and so, during the first eight years of the new company's existence, all the old pipes were taken up and replaced by others of a more durable material.

The bored wood pipes used to be made from large trees, because straight pipes, 12 feet to 20 feet in length, and from 1½ to 8 inches bore, could be got from such timber. The bore was usually equal to one-third of the diameter of the tree.

After this period cast-iron became, in England, the usual material for making pipes.

About the year 1855 wood pipes again commenced to make their appearance, but this time they were manufactured of strips of wood cemented together. This was patented by Mr. Bewicke Blackburn, and consisted in forming tubular frames by means of thin pieces of wood bent spirally and crossing each other diagonally, the interstices between the pieces of wood being filled up with a mixture of asphalt or other suitable cement, and with this cement the entire framework was enveloped and held together.

At the present time wood pipes are largely manufactured, especially in America; they are constructed of lags bound together with wrought-iron hoops, barrel fashion, and are supported on piers, for the purpose of conveying and distributing sewage on land. They are also used in mining districts for conveying water for the miners. They are in many districts preferred on account of lightness, where transport is difficult and expensive. Several very extensive pipe lines made in this fashion have been made and found very successful, amongst which may be mentioned one near Los Angeles, which consists of 4·3 miles of 14-inch pipes. The pipes are buried, the cover being generally 24 inches in depth. A 52-inch wooden stave pipe, 961 feet in length, was built to carry the water of the Santa Ana Canal across Deep Canyon, near Redlands, California. The pipe has the form of a U, with the sides inclined instead of vertical. The connecting curve has a radius of 300 feet, and its lowest point subject to a water-pressure of 165 feet, and is supported upon a wooden trestle 50 feet high in the middle. The staves are of redwood, the finished thickness being 2 inches for pressures less than 50 feet; 2·3 inches for pressures from 50 feet to 100 feet; and the remainder 2·6 inches.

WOOD PIPE JOINTS.

The original form of joint for wood pipes, as far as we can gather, was made by squaring the ends of the bored-out logs, putting them as close together as possible, with a ring of well-tarred canvas between them, and outside the pipe several thicknesses of tarred canvas or thick, coarse flannel were wound round. This joint is illustrated in Fig. 1.

Sometimes the joint was made by squaring the ends of the logs, as explained in the first example, and the connection made by means of a double spigot of wrought-iron going from 1 to 2 inches into the ends of the two pipes, as shown in Fig. 2.

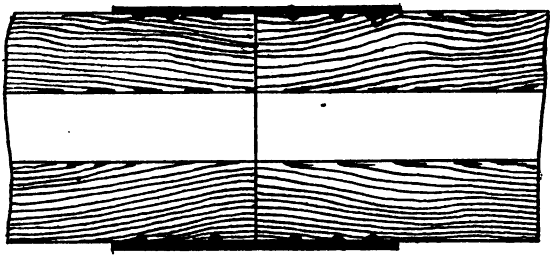

Fig. 1.

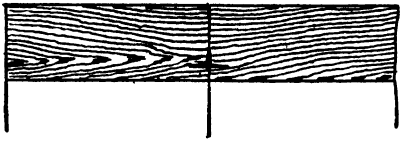

Fig. 2.

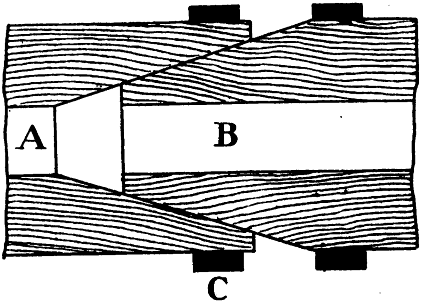

Fig. 3.

A third joint for wood pipes is illustrated in Fig. 3. This joint consists of boring out the log *A* conical to fit the conical end of log *B*; the cones are well tarred, and the pipe *B* driven tight into the pipe *A*. *C* is a wrought-iron ring or hoop forced on to the end of the pipe to prevent it from bursting when the pipe *B* is driven in.

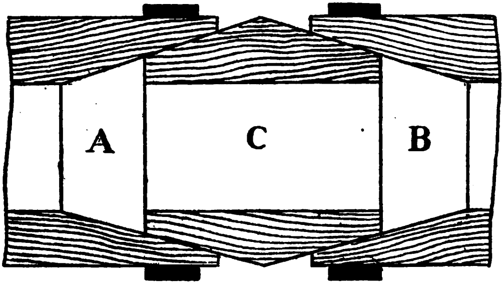

Fig. 4.

Again, at other times both ends of the pipes are conical on the inside, as illustrated in Fig. 4. In this case there is introduced, between the ends *A* and *B*, a double cone *C*,

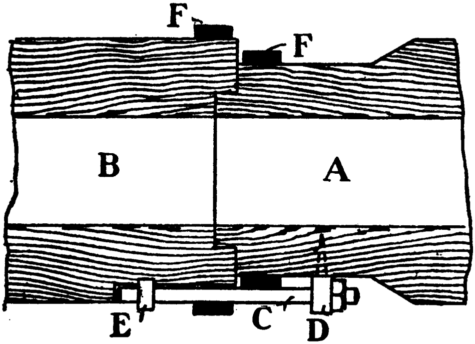

Fig. 5.

made of wood, which fits into the coned parts of the pipes. The cones are tarred and the pipes driven up tight. A strengthening hoop is driven on to each pipe end.

A very good, but at the same time expensive, joint for wood pipes made of logs, is shown in Fig. 5. The great advantage is that the joints cannot blow apart, and if the joint should happen to become leaky it can be tightened up without much trouble. It consists of four to six screws *C*, passing through wrought-iron eyes *D*, driven into the wood pipe *A*, and nuts *E* fixed into the end of the pipe *B*. The pipe *A* is recessed a little way into the pipe *B*, the joint between the two being made of hemp or flannel and tallow or Stockholm tar. Should this joint leak, it can be tightened up by turning the screws *C*, which are made square at the ends to fit a spanner; *F* are two wrought-iron hoops for strengthening the ends of the two pipes.

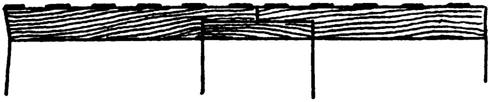

Fig. 6.

The bored-out logs have not yet disappeared, for in America they are now again become fashionable. Mr. Wychoff, a few years ago, patented a wood pipe, which is manufactured at Bay City, Michigan. These pipes have been laid in several western towns and cities in America. The chief peculiarities are, a spiral banding of hoop-iron, to increase its resistance to internal pressure and water-ram; a coating of asphaltum, to preserve the exterior of the shell; and a special form of thimble-joint.

Fig. 6 is a longitudinal section through a joint of this wood pipe, showing the manner of inserting the thimble.

They are made from white pine logs, in sections 8 feet long. The size of the pipe is limited only by the size of the suitable logs procurable for their manufacture.

CHAPTER IV

CAST-IRON PIPES

THE first mention of cast-iron pipes was in an elaborate system built at Marti, near Paris, and set to work in the year 1682. The account of this installation says:—"They drew the water by short suction-pipes from the river Seine, and forced it through iron pipes up the hill. They climbed to a height of 533 feet by a series of reservoirs and pumps." But the system came to be known as a "Monument of ignorance," probably after cast-iron established confidence as a pressure-pipe.

The first iron pipes were laid in London in the year 1746.

Professor Cawthorne Unwin states in his valuable book, *Elements of Machine Design*, Part II, that "Cast-iron pipes appear to have been first made about the year 1780 at Coalbrookdale," and as far as we can ascertain they were not introduced in America before the year 1810.

In the year 1835 it was estimated that over 100 miles of iron pipes were in use in the various systems of London waterworks.

We find that cast-iron pipes, 9 feet in length and 15 inches diameter, with ball and socket flexible joints, were laid by James Watt across the Clyde for the conveyance of water to Glasgow, and another of the same size in the year 1818, and a little later on another similar of 36 inches diameter.

There are two classes of cast-iron pipes, namely, socket pipes and flange pipes.

Cast-iron Socket Pipes.

These pipes are hardly ever used in collieries and mines as vertical pipes, on account of the difficulty experienced in separating the joints after they have been made, in case one pipe should burst; but they are very convenient when laid horizontally, having the advantage that, when there is play in the socket and lead or any other kind of jointing is run into them to make the joint, they allow of a departure from a straight line. This can be done in the socket illustrated in Fig. 7, but not in the joint where the spigot is turned and the socket bored to fit it, as illustrated in Fig. 8. The latter socket is preferred by some engineers. Another advantage with socket pipes

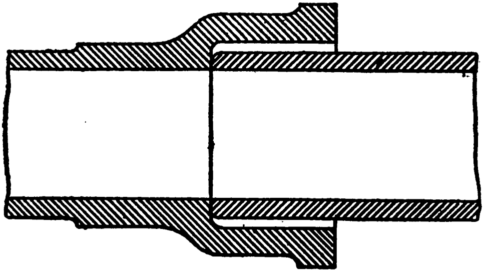

Fig. 7.

is that no exact making up lengths are required, as the spigot end of the pipe can be easily chipped or turned off to any length required, and by that means very little time is lost, in comparison with the serious delay—sometimes extending to several days—entailed by having to cast a special flange pipe.

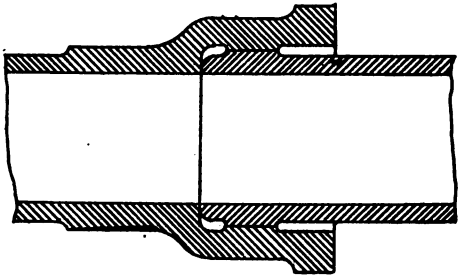

Fig. 8.

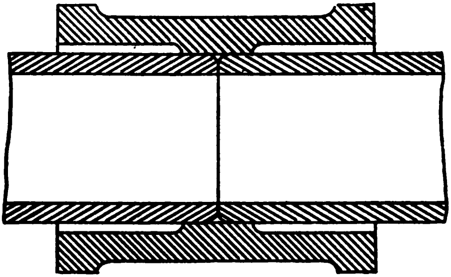

Fig. 9.

In cases where the two spigots meet, the socket is made double, as illustrated in Fig. 9, and slipped over one pipe before the last length is put in its place. Not unfrequently the double socket is made in halves, the two

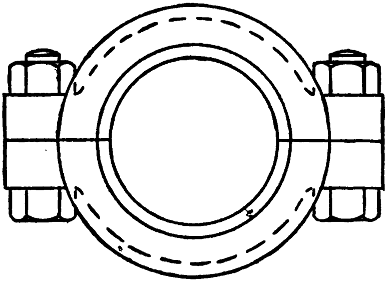

Fig. 10.

parts being bolted together round the pipe-joint. A socket of this type is shown in end view, Fig. 10.

A socket-joint of a peculiar description is illustrated in Fig. 11. In this case the lead is poured into the space in the socket by a hole made in the top side of the same.

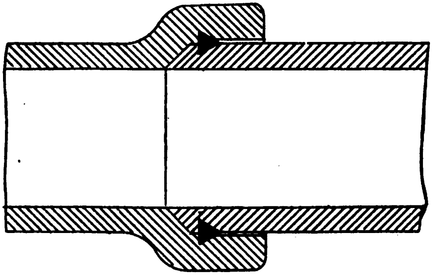

Fig. 11.

The lead cannot possibly be blown out by any internal pressure, but it is hardly possible to make a sound, tight joint, because there is no chance of caulking; again, the socket must be broken if the joint has to be undone.

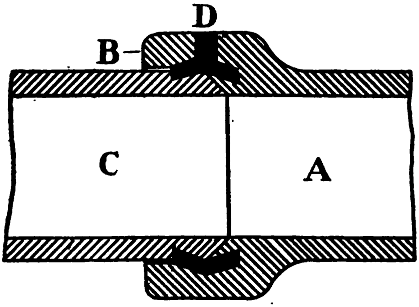

Fig. 12.

A better joint, of a similar description as the last described, is illustrated in Fig. 12, where *A* is one pipe furnished with a socket *B*; *C* is the spigot end of the next pipe. The lead is run into the curved space at *D*. The

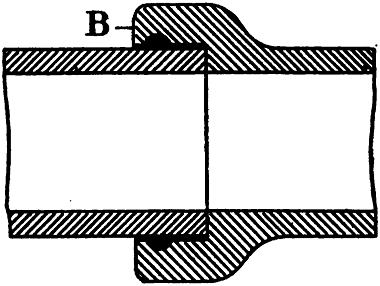

Fig. 13.

joint is made partly on the end of the spigot and partly in the socket. It is good because the lead, in cooling, contracts on the spigot and the bottom of the socket, but the difficulty is to prevent the lead from running into the pipe. There is the further disadvantage that if it is desired to disengage the pipe the socket must be broken.

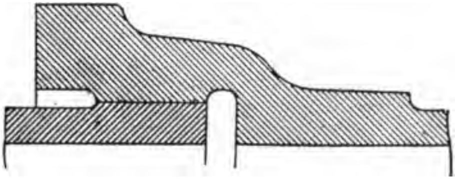

Fig. 14.

The last-named objection mentioned is prevented in the form illustrated in Fig. 13. In this the space for the lead and spun-yarn is very shallow, and a semicircular groove is formed in the socket *B*.

The standard turned and bored spigot and socket-joint employed at Liverpool is illustrated in Fig. 14, and one of the 24-inch pipes laid at Edinburgh in Fig. 15. In these two joints the proportions of contact are turned and bored to the same taper, namely 1 in 32. When the

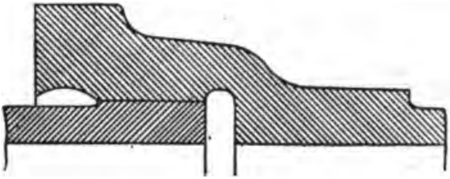

Fig. 15.

joint is made, the spigot is coated with cement of the consistency of thick paint, to which is added sal-ammoniac, to facilitate the rusting up. If necessary the space *A* in the socket is run with lead.

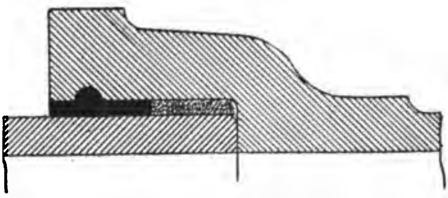

Fig. 16.

The standard lead and yarn joint employed at Liverpool is illustrated in Fig. 16, and the joint used at Paisley is shown in Fig. 17. In the latter case a rim or beading, *A*, is formed at the end of the spigot. The pipes used for the Vyrnwy works for the supply of Liverpool is

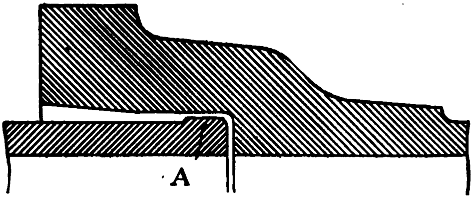

Fig. 17.

illustrated in Fig. 18. They are similar to Fig. 17, but are furnished with a wrought-iron hoop *A*, shrunk on the outside of the socket, to prevent bursting whilst being caulked.

The spigot and socket-joint adopted by Messrs. R. D. Wood & Co., of Philadelphia, is illustrated in Fig. 19.

For cases where subsidence is likely to occur, a very useful joint is that illustrated in Fig. 20. It consists of the pipe *A*, furnished with a socket. The spigot end is, as will be seen in the illustration, of a peculiar shape, and is furnished with a bevel. The joint is made by an india-rubber ring, *B*, squeezed into the socket, the space outside the ring being filled up with cement.

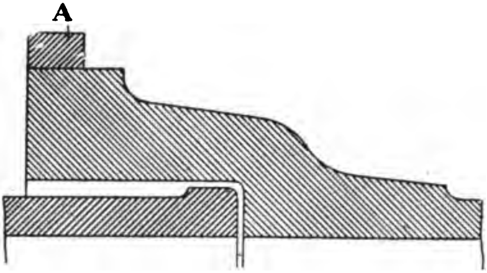

Fig. 18.

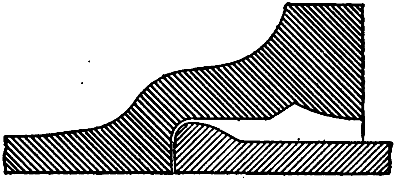

Fig. 19.

A joint similar in principle to Fig. 12, but having two spigot ends and a loose double socket, is shown in Fig. 21. The socket has a bend in it, and the spigots have corresponding bevelled grooves, and are butted against bevelled parts; the lead being run in through a hole in the top of the socket fills up the space, thus forming a band of lead of a double wedge shape, which, contracting during cooling, draws the bevel parts close, and thus forms a joint sufficiently tight to resist ordinary internal pressures. A drawback to this method of jointing is the impossibility of making the ends of the pipe perfectly square without turning them, thus increasing their cost, and the lead is therefore able to get into the pipe, making it impossible to tell when the joint is full.

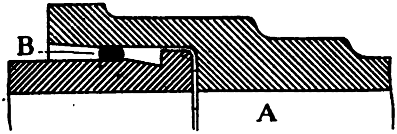

Fig. 20.

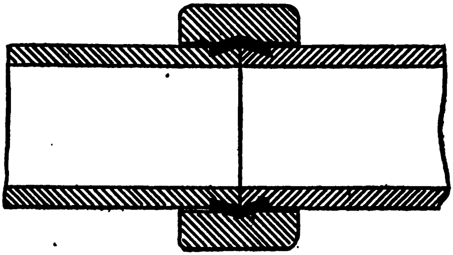

Fig. 21.

CAST-IRON FLANGE PIPES.

Flange pipes are mostly used for pump work, hydraulic mains, steam pipes, and in places where a straight line of piping has to be laid down. The joints are easily made, and at any time one pipe can be removed and replaced without disturbing its neighbour, except when a small spigot is used, which is sometimes the case, as will be seen later on in this chapter.

The most common flange pipe joint, in collieries and mines, is the one illustrated in Fig. 22. It consists of a lead or wrought-iron ring—the former being preferable on account of the iron corroding—wrapped round evenly with flannel or common woollen cloth, soaked in Stockholm tar. When wrought-iron rings are used, they should be one-eighth of an inch thick, turned true. When lead rings are adopted, the flanges of the pipes need not be faced on account of the soft nature of the lead; they are, however, faced in first-class work, to ensure a perfectly straight line.

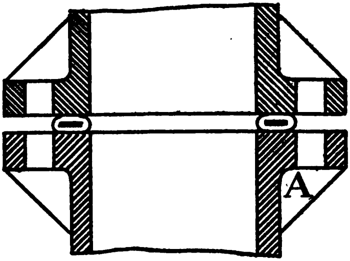

Fig. 22.

Sometimes the joints are made simply of small lead pipes scraved to form a perfect even ring.

A cheap and efficient joint consists of an india-rubber ring placed between the two flanges, as shown in Fig. 23.

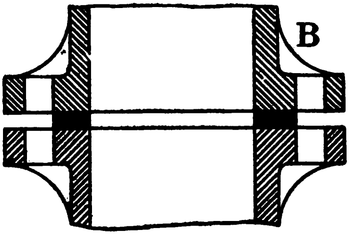

Fig. 23.

Again, at other times flange pipe joints are provided with a small spigot and faucet. It is not necessary to make the spigot very deep, the object being to keep the joint ring in position until the joint is made. This is shown in Fig. 24. Flange pipes with spigot and faucet are sometimes made as illustrated in Fig. 25, with the joint ring placed at the bottom of the faucet. The ring

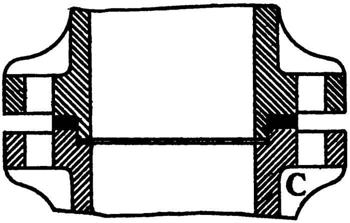

Fig. 24.

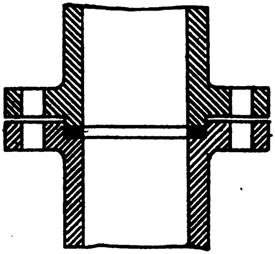

Fig. 25.

is made of gutta-percha, or lead carefully wrapped with lamp-cotton without tar or oil.

With heavy pressures the india-rubber ring, shown in Fig. 24, is apt to be forced out of the joint, and when some liquids, such as ammonia, are pumped or flowing through the pipes, the india-rubber or gutta-percha, placed as shown in Fig. 25, is likely to be dissolved and drawn into the pipe. In such cases it is best to turn a groove in one flange and a spigot in the other, as illustrated in Fig. 26, and to place an india-rubber or gutta-percha ring in the groove. Again, a groove may be turned in one flange, and a projecting ring corresponding with the groove on the other flange, whilst an india-rubber or gutta-percha ring is placed in the groove. This is illustrated in Fig. 27.

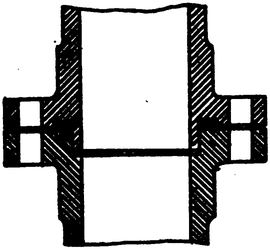

Fig. 26.

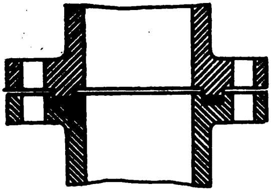

Fig. 27.

For heavy pressures pipe-joints are made in the manner illustrated in Fig. 28. This joint consists of a spigot turned to fit a faucet, the latter being bored out and chamfered at the mouth. A gutta-percha cord—which is made into a ring by cutting its ends at an angle, dipping them in hot water, and then pressing them together by the finger and thumb—is placed round the spigot. This joint is simple, cheap, and very effective, and can safely be used for pressures up to about 700 lbs. per square inch.

Fig. 29 illustrates another gutta-percha joint, which consists of two ordinary flanges faced straight across and having a ring cut with a diamond-pointed tool in each flange, with the inside of the groove straight; when the two flanges are put together the groove forms a triangular recess. A gutta-percha cord, made into a ring in the manner already described, is put into the groove before the flanges are bolted together. It will be noticed that when the pressure is introduced into the pipe, it acts on the flat surface of the triangle, and tends to force the gutta-percha ring into the space between the flanges, by that means forming a perfectly sound joint. There is, however, a great difficulty in horizontal pipes to get the ring exactly in its right place.

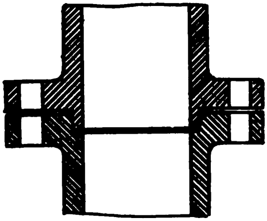

Fig. 28.

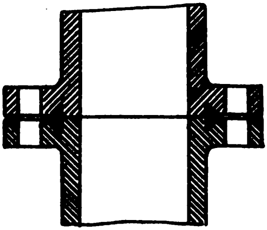

Fig. 29.

Without a doubt the best joint for cast-iron pipes exposed to a great pressure is the one illustrated in section

Fig. 30, and plan Fig. 31. It was originally introduced by Lord Armstrong for his hydraulic machinery. In this case both the spigot and the faucet are turned to an angle of 22½ degrees, so that a triangular space formed between them has an angle of 45 degrees, and a gutta-percha ring is placed at the bottom of the faucet. For cast-iron pipes the width of the faucet all round the bore of the pipe is $\frac{3}{8}$ of an inch, and $\frac{3}{8}$ of an inch is the greatest

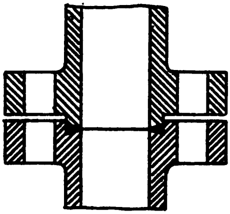

Fig. 30.

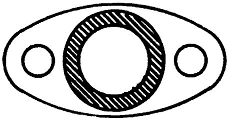

Fig. 31.

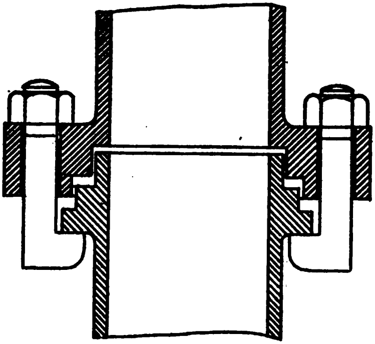

Fig. 32.

depth of the spigot. For a 3-inch pipe the recess is 3¾ of an inch diameter.

Richardson's patent universal india-rubber joint for hot-water pipes, which is also very useful for sewage and drainage works, is illustrated in sectional elevation, Fig. 32. It will be noticed that there is only a flange on one pipe, the other has only a small collar which is gripped by hook bolts. These joints have been tested with pressures up to 125 lbs. per square inch.

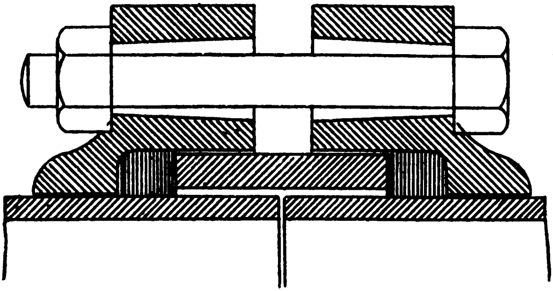

Fig. 33.

Jones' Improved Flange-pipe joint is illustrated in longitudinal section Fig. 33. In this joint the ends of the pipes and connections are all alike. The flanges are round, small in diameter, and cast on solid; four bolts and nuts are used at each joint. The middle ring fits into recesses in the ends of the pipes, the india-rubber ring is compressed between the bevelled faces of the flanges, thus making a perfect joint which possesses a certain amount of elasticity.

For cut lengths or final joints, malleable flanges are used, which may be shrunk on hot, or fastened on cold with a small punch, thus avoiding the delay of waiting for special lengths being cut.

This joint is very useful for hot-water and steam-heating apparatuses.

CHAPTER V

CAST-IRON BALL-AND-SOCKET PIPES

WHERE the ground is very uneven, so that sufficient play cannot be obtained in the sockets, the ball-and-socket system must be resorted to, as illustrated in sectional elevation Fig. 34, and plan Fig. 35. It is also sometimes convenient, whilst sinking wells or pit-shafts,

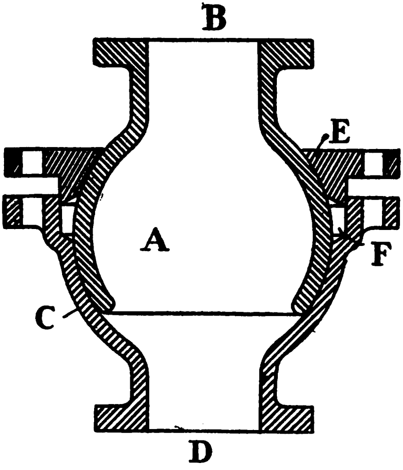

Fig. 34.

to have the suction pipe so arranged that it can be swung out of the way when sinking under the line of the pump. The joint consists of a ball *A* turned true, the flange *B* being bolted to the end of a pipe, or direct to the suction flange on the pump. *C* is the socket which is bolted by the flange *D* to the end of the next pipe. This socket is bored in the inside so that the ball may be perfectly air- and water-tight. *E* is a gland fitted to the socket pipe at its stuffing-box *F*. The gland is also bored out on the inside to fit the ball, and is made in halves to allow it to be fitted. Fig. 35 shows holes for the six gland bolts, by means of which the packing in the stuffing-box can be tightened.

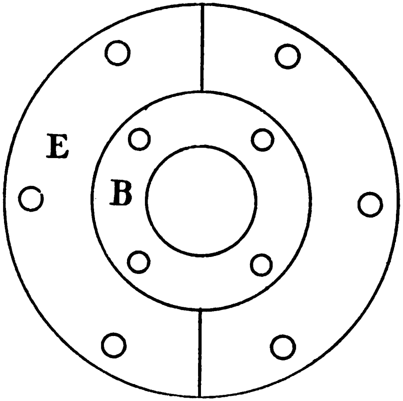

Fig. 35.

A cast-iron ball-and-socket joint manufactured by Mr. Walker, of Fenton, Mich., is illustrated in half-section and half-elevation, Fig. 36. The ordinary stuffing-box is dispensed with. One advantage of this joint is that where it is necessary to be deviated to any extent after being put together, instead of cutting away the lead gasket, the slack is taken up by springs in the follower *A*. The gasket *B* is recessed into a groove turned out of the socket-end of the joint, and as the ball is turned

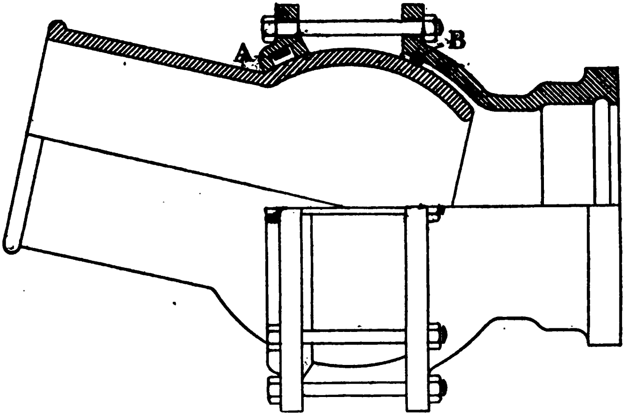

Fig. 36.

true it will be readily seen that any desired tension can be put upon the joint, either before or after laying the pipe. Non-corrosive seats are inserted in the follower to take the strain instead of the springs. These joints were successfully used on a 20-inch pressure-main across the Hudson river at Fort Edward.

Messrs. R. D. Wood manufacture three distinct types of ball-and-socket joints, illustrated in Figs. 37, 38, and

39. Fig. 37 is that they usually employ, and admits of the lead gasket moving upon the interior surface of the socket, which latter is carefully machined. This design is sometimes modified by adding one or more grooves

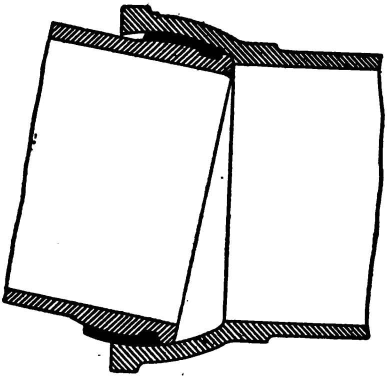

Fig. 37.

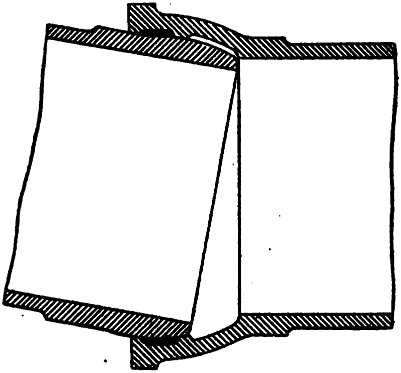

Fig. 38.

upon the ball. In Fig. 38 the lead is entirely confined within the socket, the ball being the turned portion. The more expensive joint, intended for large sizes of pipes, especially where they are used for conveying water under considerable pressure. This joint has a split retaining ring or gland *A*, forming a very secure connection. For large diameters these joints made in short lengths may be used for convenience in handling or in connection with a line partly made up of ordinary socket-and-spigot pipes. This latter joint is shown in sectional elevation, Fig. 39.

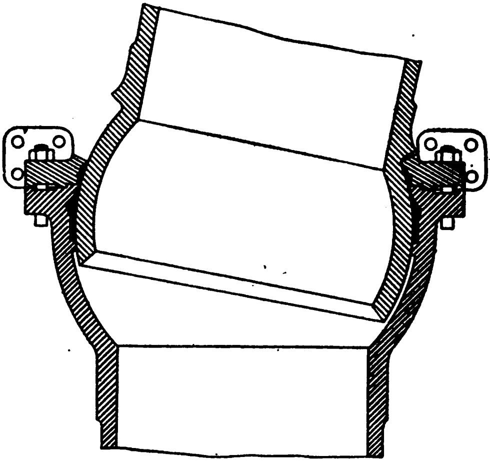

Fig. 39.

CHAPTER VI

GENERAL REMARKS ON CAST-IRON PIPES, AND RULES AND FORMULÆ RELATING TO THEM

The rising-main or delivery-pipes for Pumps. The thickness of metal should be calculated for every 200 feet head. Prime cost, carriage, difficulty of handling in pit-shafts and wells—all these conditions render it desirable that the weight should be reduced as far as possible, but of course this must not be done at the expense of efficiency.

The cast-iron pipes for mines and collieries are invariably made in 9-feet lengths, with a few matching or making-up pieces 6 feet, 3 feet, and 2 feet long. For water and sewage works small pipes are made 6 feet long, medium sizes 9 feet long, large sizes 12 feet long; but extra large pipes are sometimes made 4 feet to 6 feet in length, according to the weight.

The ribs between the bolt-holes in the flanges are made of various shapes. The design shown at *A*, in Fig. 22, page 33, is not to be recommended, as ribs of this pattern are invariably in the way of the spanner when the bolts are tightened up. Many engineers, who object to the rib *B*, illustrated in Fig. 23, page 34, because it does not strengthen the flange at the periphery, adopt the rib shown at *C*, in Fig. 24, page 34, which is stronger at the periphery of the flange, and still leaves ample room for the spanner.

Blow-holes frequently occur at the ribs, therefore some designers prefer the method of gradually increasing the thickness of the metal towards the flange, increasing the thickness of the latter, and having a large radius at the root, as illustrated in Fig. 40.

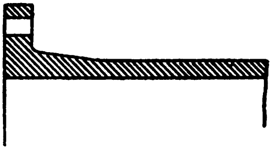

Fig. 40.

The bolt-holes in the flanges should be made rectangular, and cast in the flanges. They should be one-eighth of an inch wider, and about one-quarter of an inch longer than the diameter of the bolts. Some pipe-founders make the holes even larger; for instance, for 1¼-inch bolts they make the holes 1½ inches wide by 1⅝ inches long.

Some do not face the flanges of pipes straight across, only making strips about one-eighth of an inch deep. This facing strip should be of the same diameter as the distance between the inside of the bolt-holes in the flanges. The space left by the facing strips on the flanges is useful when the joint has to be broken, steel wedges can be driven in to loosen the joint.

In casting pipes the core must be carefully placed in the mould so as to give equal thickness of metal all round the pipe; the core-bar should be as large in diameter as possible to prevent sagging in the middle. Chaplets should be used sparingly, because the metal is liable to blow and become spongy round them. The core-boards should be perfectly straight and level, or the pipe will be thicker in the middle or at the ends, as the case may be.

The mixture of the iron for casting pipes must be carefully considered, because the different kinds of iron have different fusion point and different rate of cooling. The pipes must not be taken out of the sand too soon, or they will be what is termed hide-bound by being cooled too rapidly, and with flange pipes the flanges become so hard that they cannot be properly faced true. If the casting is not cooled gradually, the metal round the periphery of the pipe—that is, the skin—will be lighter in colour and the grain closer in consequence of chilling. A pipe when broken should present a bluish-grey colour and close-grained texture. Phosphor in the iron makes it brittle. Cold-shot iron should never be used for pipes.

Small pipes may be cast horizontally, but better at an angle of 45 degrees. Large pipes ought to be cast vertically, as this makes a better casting, besides preventing the core from floating. When socket-pipes are cast, the socket should be at the bottom of the mould, in fact it is sometimes specified that the pipe should be cast 12 inches longer at the spigot and afterwards turned off.

To find the number of Pipes in a Pile.

Count the number of pipes in the bottom row, add 1, and multiply the sum by one-half the number in the bottom row.

To find the number of Pipes in a Triangular Pile.

Add the one at the top to the number of pipes in the base, and multiply by one-half the number in the base.

In calculating the thickness of cast-iron pipes, allowance must be made for the core being slightly out of the centre, and the sagging of long cores, as the strength of the pipe depends upon the thinnest part. The factor of safety given ought to be 10, although many engineers employ 8, and some only 6. The thickness, except for very small pipes, should not be less than one-half inch for any pressure.

All pipes should be carefully tested up to double the working pressure, although three or four times the working pressure is sometimes specified; this appears to be putting an undue strain on the metal. During the test each pipe should be tapped all over with a hammer to detect blow-holes, or, as some term them, air-bubbles.

The resistance which a pipe offers to the internal pressure tending to burst it is equal to the tensile strength of its two sides, and the effective area of that pressure is the internal diameter of the pipe. Now, if we take the tensile strength of cast-iron as 15,000 lbs. per square inch, the thickness of a pipe will be found by the formula:—

$$T = \frac{0{\cdot}433 \times H \times R}{15{,}000} = 0{\cdot}0000288 \times H \times R;$$

in which H = the head of water in feet;

R = the radius of the pipe in inches;

T = thickness of metal in inches and fractions of an inch;

0·433 = the pressure of a column of water one foot high;

15,000 = tensile strength of cast-iron in lbs. per square inch.

When D = diameter of pipe in inches, the formula becomes—

$$T = 0{\cdot}0000144 \times H \times D,$$

and if we use a factor of safety of 10, we get—

$$T = 0{\cdot}000144 \times H \times D;$$

or

If the pressure is given in lbs. per square inch, the following formula may be used:—

$$T = (0{\cdot}000125 \times P \times D) + C;$$

in which

P = lbs. pressure per square inch;
C = a coefficient = 0·37 inch for pipes less than 12 inches diameter;
= 0·5 inch for pipes from 12 to 30 inches diameter;
= 0·6 inch for pipes from 30 to 50 inches diameter.

Rules for Weight of Cast-iron Pipes.

The usual method adopted for calculating the weight of cast-iron pipes consists in finding the cubical contents of the metal in cubic inches, and multiplying that by the weight of one cubic inch of cast-iron = 0·26 lb.

Example.—Taking a pipe 12 inches internal diameter, ½ inch thick, 9 feet long, we have outside diameter 13 inches = 132·732 square inches area, internal diameter 12 inches = 113·097 inches area.

132·732 − 113·097 = 19·635 square inches sectional area.
9 feet = 108 inches, hence
19·635 × 108 = 2120·58 cubic inches of cast-iron, and
2120·58 × 0·26 = 551·35 lbs. = 4 cwt. 3 qrs. 19 lbs.

The two flanges, or one socket, are usually reckoned equal to one foot length of pipe.

Another rule for calculating the Weight of Cast-iron Pipes.

$$W = 2{\cdot}45\,(D^2 - d^2);\ \text{or}\ 2{\cdot}45\,(D + d) \times (D - d);$$

in which W = weight per lineal foot, in lbs.;
D = external diameter of pipe in inches;
d = internal diameter of pipe in inches;
2·45 = a constant.

A very useful Approximate Rule for the Weight of Cast-iron Pipes.

Rule.—For a pipe 9 feet long, with flanges at each end, and 1 inch thick, allow 1 cwt. for every inch in diameter, keeping the thickness and weight proportional, either more or less.

Example.—A 12-inch pipe, 9 feet long, flanges at each end, 1 inch thick, will weigh approximately 12 cwt.

A 12-inch pipe, 9 feet long, flanges at each end, ¾ inch thick = 9 cwt.

A 10-inch pipe, 9 feet long, flanges at each end, ½ inch thick = 5 cwt.

CHAPTER VII

WROUGHT-IRON, STEEL, COPPER, AND BRASS PIPES

AFTER many experiments Mr. James Russell, in the year 1824, succeeded in the manufacture of pipes made of sheet-iron strips welded together at the seams. These have now to a certain extent superseded lead pipes for domestic purposes. One great objection to wrought-iron and steel pipes was that, if they were exposed to the weather, corrosion was certain to take place quicker than in cast-iron pipes, but this objection is entirely overcome by coating the pipes with an anti-corrosive composition.

Large welded wrought-iron or steel pipes with longitudinal straight seams must, for the sake of stability, be made of a thicker material than is necessary to withstand the internal pressure. Many attempts to obviate this, however, have been made at various times The first attempt we are aware of, is the patent secured by Mr. William Childs, Junior, in the year 1854, in which he claims an idea for winding strips of wrought-iron spirally, and welding up the seams. The strips of metal were tapered and chamfered at the edges so as to make a scarf joint when brought together, and the pipes or tubes were formed by winding the ribbons or strips round a cylinder, the edges being welded as quickly as they were brought together. This idea has of late years formed the basis of many experiments in America.

Wrought-iron lap-welded pipes are by some engineers considered superior than those drawn solid, although it is somewhat difficult, at first sight, to understand how a weld can be so reliable as a pipe made without a seam.

The method of drawing tubes solid was greatly improved by Mr. Charles Green, in the year 1838. Its introduction resulted in considerable improvements in the welded tubes. Great credit is due to Mr. W. S. Sutherland, of Birmingham, for the introduction of his gas-welding apparatus, which is employed for welding all sizes of tubes and pipes up to boiler flues. Mr. Green claims to have effected improvements in making solid drawn tubes or pipes of brass and copper—all solid pipes previously made was cast-iron and lead. He cast copper and brass in short lengths with the same or nearly the same internal diameter and of a larger external diameter than those of the intended tube when finished, and, by means of a drawbench, afterwards drew the pipes through dies until they obtained the required external diameter and length.

About the year 1853 wrought-iron pipes with longitudinal straight seams were used on the Pacific Coast. This was the usual method at that time, and even more recently, many towns are still supplied with water under considerable head from pipes of this kind, which had been more than thirty years in service.

The first occasion on which steel water-pipes came to be used was in the year 1881, when Kimberley Waterworks had to buy some 1500 tons of water-mains, and (there being no railway at the time) there were about 500 miles of ox-wagon carriage. The cost of freight alone exceeded £50 per ton.

It was obvious that cast-iron pipes were impossible. For this purpose, therefore, Messrs. Thomas Piggott & Co., of Birmingham, suggested welded steel pipes 14 inches internal diameter, and $\frac{1}{4}$ of an inch thick, and 18 inches diameter, by $\frac{5}{16}$ of an inch thick, and the order was executed, saving Kimberley Waterworks a very large sum of money in freight. Since then, in South Africa, many water companies have followed the example, and water-mains for Pretoria, Durban, Klerksdorp, and Buluwayo were all made of steel. Besides these, the Johannesburg Waterworks have from time to time made large contracts for steel pipes.

Thus far we have stated what has happened in the question of steel pipes away from Great Britain, and chiefly in our colonies, and it was supposed by some engineers that the demand for steel pipes was only in cases where there was very expensive inland freight.

There has proved to be, however, an even larger demand in this country in connection with large water schemes, and our ablest engineers have ordered steel pipes wherever the pressure has been highest, and wherever the main has had to be laid in some places which would prove to be afterwards inaccessible. In the Liverpool water scheme, and in Sydney Waterworks, sections of the line were made in steel.

It was not until 1893 that Mr. James Watson, of the

Bradford Waterworks, determined to make a pipe line of large diameter in steel. It was found that in pipes of large diameters cast-iron proved a very treacherous metal. In small diameters the factor of safety was greater, but in larger diameters so thick was the metal and so great was the surface, and so difficult was it to discern the defects, that cast-iron, where pressures were high and diameter large, had to be abandoned.

To give an illustration:—If a number of pipes of large diameter, both of cast-iron and of steel, were tested to destruction, supposing the calculated bursting point in each description of pipe was 1200 lbs. per square inch, it has been stated that every steel pipe would stand 1150 lbs. per square inch, and all burst at about the same pressure; whereas in the case of cast-iron pipes it is alleged that the bursting would begin at 300 lbs. per square inch, and continue at all pressures.

Some of Messrs. Piggott's pipes have been laid now for eighteen years, and the last reports show that they are still uninjured by corrosion. The proper coating is, of course, a most important matter. The manner of coating, which is quite as important as the mixture employed, is of course kept secret; but we believe that one great thing is to remove all rust, and clean thoroughly by a coating of oil, which is afterwards dried off in an oven, and then the pipe is passed through several baths of an asphalt composition, which gives a coating of good thickness and of perfect elasticity, so that it will expand or contract with the expansion and contraction of the pipe, under varying temperatures.

The welded wrought-iron or steel pipes are made from 8 inches diameter upwards to any diameter, but where the pipes are made from a single plate the size is of course limited by the size of a single plate procurable. Approximately, for welded pipes one-quarter of an inch thick by 26 inches diameter is the largest for which a plate can be obtained. Where the thickness is greater than one-quarter of an inch, plates can be had for the formation of pipes about 28 inches diameter.

Riveted pipes, built up of plates about 4 feet wide, can be made of any diameter. Welded pipes can now be made 17 feet 6 inches long, and a not unusual length for riveted pipes is 24 feet.

Riveted pipes are tested up to a pressure of 200 lbs. per square inch, as that is about the greatest pressure at which a double-riveted joint will keep tight. Welded pipes are tested to a much greater pressure. Pipes of 8 to 18 inches diameter and one-quarter of an inch thick are tested up to as much as 400 lbs per square inch, although the usual test pressure for ordinary-sized pipes one-quarter of an inch thick is 250 lbs. per square inch.

Mr. M. S. Earshaw Howell in the year 1892, with a view of testing the welding of steel tubes by rolls, took a 4 feet 8 inch length of tube so welded, and cut it into rings 2 inches long, of which there were 28. The first ring was then cut open along the weld, and the next ring was cut open opposite the weld, and similarly for the rest of the 14 pairs forming the whole length of the tube. The rings so cut were then opened out to form flat bars, which were tested for tensile strength in the usual way. Of the 14 bars which had the weld in the middle of their length, 6 did not break at the weld at all. The whole tensile strength of the 14 solid bars added together was 317·94 tons, giving an average of 22·71 tons per square inch. The total tensile strength of the 14 welded bars was 315·95 tons, giving an average tensile strain on the weld of 22·57 tons per square inch, which showed that they were nearly as strong as the solid bars. Mr. Howell took three inches as a datum length of elongation for measuring the percentage, which in the 14 solid bars amounted to a total of 529·80, or an average of 37·84 per cent. extension. The percentage of elongation in the 14 welded bars amounted to a total of 424·89, giving an average of 30·34 per cent. extension, so that, although the elongation of some of the welds was not really low, it was not nearly as good as of the solid, but for all practical purposes it was sufficiently near.

In 1868 two mains were laid across Humbug Cañon. They were 26 inches in diameter, 1194 feet long, of common iron one-sixteenth of an inch thick, single-riveted, and delivered water under a head of 120 feet, the tensile stress being 11,500 lbs. per square inch.

The Abendroth and Root Manufacturing Company, of New York, made wrought-iron pipes with lap-welded spiral seams, by that means increasing the strength. Large pipes have been made of steel with spirally lap-welded seams. They can be made of thinner metal and yet show greater strength. This has been proved by certain tests, which exhibit the following results:—

A 6-inch will carry 1106 lbs. per square inch, and will burst under 1800 lbs. per square inch;
A 12-inch pipe was tested at 475 lbs. per square inch, and will carry 900 lbs. per square inch without fracture;
A 6-inch spirally welded steel pipe will weigh 5·2 lbs. per foot run;
Ordinary tap-welded pipes 18·77 lbs. per foot run;
Medium cast-iron pipes 28·28 lbs. per foot run;
12-inch spirally welded pipes weigh 10·46 lbs. per foot run;
Ordinary lap-welded 54·65 lbs.
Medium cast-iron pipes 77·36 lbs.

Another advantage is that the greater the pressure the tighter the joint is, for it has been found that defective spirally welded tubes that leak under 20 lbs. pressure per square inch become tight at 50 lbs. per square inch, and remain so at 350 lbs. per square inch. The strength obtained in light pipes, if the material is used to the best advantage, is quite surprising. A 6-inch pipe made of No. 14 B.W.G. iron, of good average quality, with 33,000 lbs. per square inch ultimate strength, has a proof strength of 918 lbs. per square inch, and ultimate strength of 1383 lbs. per square inch. A 12-inch pipe of the same thickness has a proof strength of 456 lbs. and an ultimate strength of 691 lbs. per square inch.

A rivetless seam pipe has been patented by Mr. Mephen Ferguson in Australia and elsewhere; it has a dovetailed longitudinal joint; it is made by swelling the longitudinal edges of the plates and bringing them together in grooves made in the opposite sides of a longitudinal bar. The bar is then closed by pressure upon the swollen edges of the plate. A pipe of this kind with two longitudinal joints was tested by Professor Unwin, from which strips with the joints in the middle of each were cut and tested. In the case of 5 out of 6 tests, the strips broke through at the solid plate and not at the joint. A pipe 4 feet long, ⅛ of an inch thick, and 12 inches internal diameter, with two of the patent rivetless seams was tested with an internal pressure of 800 lbs. per square inch, when the test was stopped by leakage at the ends, which had nothing to do with the construction of the pipe. Subsequently about 850 lbs. per square inch was got on the pipe before leakage at the ends again stopped the test. In a third test the pressure momentarily reached 900 lbs. per square inch. The pipe was bulged, but there was no leakage at the longitudinal joints, and they did not appear to be injured, though the stress on the steel must have reached nearly 20 tons per square inch when the internal pressure of 900 lbs. per square inch was applied. This is the class of pipe adopted for the Coolgardie Goldfield water supply from the Helena river, instead of the specified riveted large pipes.

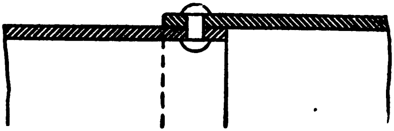

Fig. 41.

The method usually adopted for joining the circumferential seams of the short lengths of riveted or welded wrought-iron or steel pipes is illustrated in Fig. 41, but this is not a good practice, as it causes obstruction to the flow of the liquid, and lodgment for sediment and dirt. A better, though more costly, method is shown in Fig. 42, in which the inside diameter of the pipe at each joint is enlarged so as to form a socket.

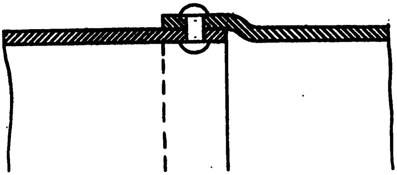

Fig. 42.

A full-bore pipe, as sometimes used by Messrs. Piggott, is illustrated in Fig. 43. In this case the rivets are out of the way of the flowing liquid, so as to cause no friction. Another advantage is that the sediment always settles first on the side of the rivet heads, therefore there is less sediment adhering to pipes with this class of joint, besides leaving a clear course for pipe-scrapers.

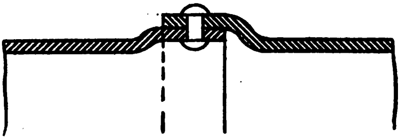

Fig. 43.

Mr. Watson designed the Bradford pipes 36 inches diameter, by $\frac{5}{8}$ of an inch thick, in accordance with the illustration, Fig. 44, and these have been laid and proved to be absolutely successful. Since that Mr. L. L. Macassey, of the Belfast Water Commissioners, has designed steel pipes of a similar diameter, and of almost similar description, and also Mr. James Mansergh, the engineer to the Birmingham Corporation, has designed 42-inch pipes of varying thickness for the Birmingham water supply from Wales.

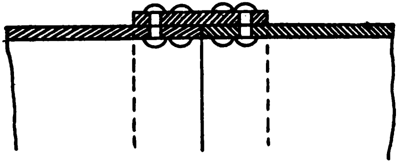

Fig. 44.

WROUGHT-IRON, STEEL, COPPER, AND BRASS PIPE JOINTS.

There are three kinds of joints for these classes of pipes, namely:—

Screwed joints;
Socket joints; and
Flange joints.

SCREWED JOINTS.

Screwed joints for small tubes are very common, but they are not applicable to large pipes, on account of the great waste of material, for the thickness of a pipe must be calculated for its thinnest part. From the section of a screwed tube shown in Fig. 45, it will be seen that the thinnest part is at the bottom of the thread; hence all the metal outside the dotted lines is pure waste, and the pipe would be just as strong with the use of less material if it were swelled at the ends and screwed, as illustrated in Fig. 46. But this feature adds greatly to the expense, and is never recommended for pipes that are more than 6 inches diameter.

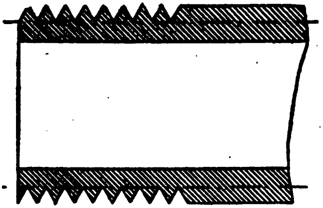

Fig. 45.

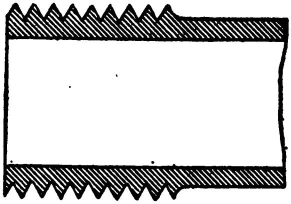

Fig. 46.

The ordinary wrought-iron joint, formed by a common socket or collar, as it is sometimes termed, and the running joint, are so well known by all practical men that it would be useless to make any remarks about them, but a very good method to ensure a joint on wrought-iron tubes of small diameter, for comparatively heavy hydraulic pressures, is illustrated in Fig. 47, in which *A* is the end of one length of piping, *B* another length coupled up to it, and *C* is a right-and-left-hand coupling. It will be

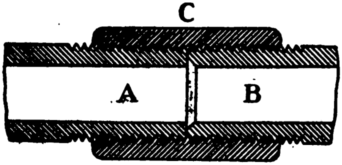

Fig. 47.

seen that the pipe *A* is faced perfectly flat, and the end *B* turned to a knife-edge, which edge, when the pipes are drawn together by the coupling, forms a sound joint against the flat face of the end of the pipe *A*.

Another plan, illustrated in Fig. 48, consists of the ordinary right-and-left-hand screw coupling *C*, and a short piece of tube or ferrule *D*, introduced between the ends of the pipes *A* and *B*. This ferrule is made of a tough but comparatively soft and expansive alloy. In addition to the joint at the screwed part, they are also made by the two ends of the pipe butting against the ferrule. If the pipe should happen to be screwed too small to admit of a good joint being made in the usual way, the addition of the ferrule enables one to be made with certainty, and with the extra advantage of obtaining a uniform internal diameter of the piping. In some cases a round or diamond-shaped copper ring is adopted instead of the ferrule *D* in Fig. 48.

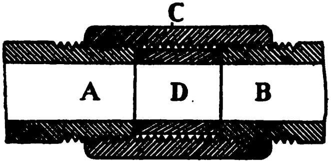

Fig. 48.

The American wrought-iron oil-line pipes for petroleum are specially made of lap-welded wrought-iron of selected material, tested critically before leaving the mills, and are known in the trade as oil-line pipes. The lengths of

18 feet are fitted at each end with a coarse and sharp-cut taper threads nine to the inch. The taper is usually ¾ of an inch to the foot for 4-inch pipes.

WROUGHT-IRON AND STEEL SOCKET PIPES.

The common socket for wrought-iron and steel pipes is illustrated in Fig. 49; *A* being the pipe to which the socket *B* is riveted; *C* the pipe-end forming the spigot. The joint is made in the usual manner with spun-yarn and lead, or rust cement.

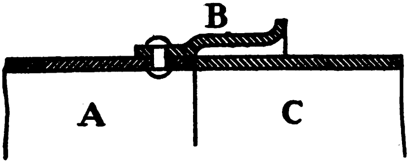

Fig. 49.

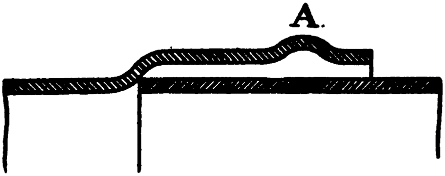

Fig. 50.

Fig. 50 is a good design of socket for welded wrought-iron or steel pipes. It is expanded on the ends of such pipes, but it has the disadvantage that the thickness of the metal is reduced at *A*, the point of the largest diameter, and therefore where the greatest strength is required.

The Duncan joint is shown in Fig. 51. The socket *B* is riveted to the pipe *A*, and can be rolled of either wrought-iron or steel, and of thicker metal when greater strength is required. At other times the socket is shrunk on to the pipe and riveted to it. Another advantage of this socket joint is the bearing surface at the spigot *C* against the bottom of the socket. It is so designed that the surfaces of contact are spherical, and allow a horizontal and vertical angular deviation up to the limiting point at which the spigot end of the pipe touches the extreme end or mouth of the socket. The spigot *C* is riveted to the end of the pipe *D*.

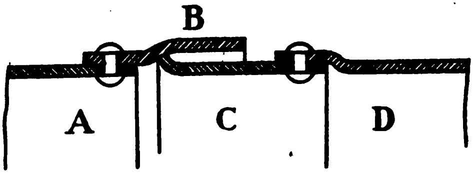

Fig. 51.

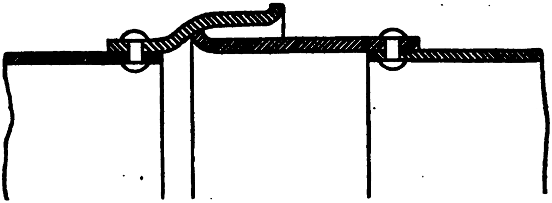

Fig. 52.

Another very good socket joint very similar to the last-mentioned, and known as Riley's stamped steel socket joint, is illustrated in Fig. 52. Greater stiffness is obtained at the mouth of the socket by the rim, which is very favourable for caulking with lead. Another advantage of stamped sockets is that they are truly cylindrical, and are stronger for being without welded seams.

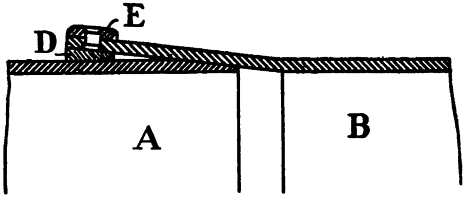

Fig. 53.

Messrs. Piggott's socket, Fig. 53, is made in one piece with the pipe *B*, the rim being strengthened by a wrought-iron hoop *E*, riveted to it; *A* is the spigot end of the next pipe, which is chamfered off at the extremity. Hemp is placed at the bottom of the socket, and *D* is the lead for making the joint.

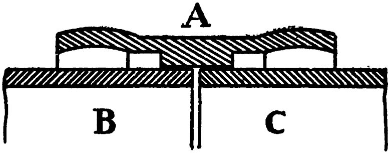

Fig. 54.

Fig. 54 shows two sockets *A* made into one, both pipes *B* and *C* having plain ends. This appears to be a very simple joint, but it seems as if, with these small collars, considerable difficulty might be experienced in laying the pipes correctly. The difficulty of getting the two pipes and the collar all truly concentric is also considerable; in caulking at one side of the collar or socket, there will be great danger of disturbing and loosening the joint on the other side. These joints were made for the Kimberley Waterworks, laid down in the year 1884, the pipes being, as previously stated, 14 inches and 18 inches diameter.

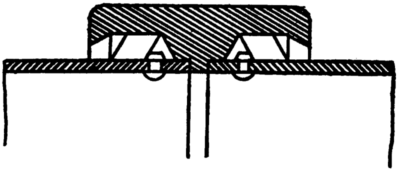

Fig. 55.

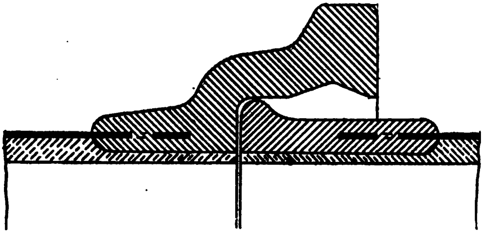

Fig. 56.

An improvement upon the last described socket joint, called the converse lock-joint, is shown in Fig. 55. It is made of cast-iron and consists of a collar with lead space at both ends of the pipe, the collar forming recesses into which projecting rivet heads, fixed on the ends of the pipes, are riveted and locked by moving the pipe through a small part of its circumference.

A cast-iron socket for a steel cement-lined pipe is illustrated in Fig. 56. Some engineers have experienced a difficulty with the ordinary wrought-iron sockets, and for that reason this socket was devised. This joint has been successfully used for pipes up to 20 inches diameter. The shells are riveted up in the usual manner, and then the pipe is set up on end in the foundry, and a socket is moulded round one end and cast. A spigot is cast in the same manner on the other end of the pipe.

WROUGHT-IRON, STEEL, COPPER, AND BRASS FLANGED JOINTS.

The flanges for wrought-iron or steel pipes are usually also made of wrought-iron, sometimes stamped out of steel plates; but for small hydraulic work they are screwed on, and should be slightly riveted over; on large pipes they are mostly riveted on to the pipe, although sometimes they are screwed on, as will be presently illustrated. They can be formed by flanging the pipes themselves; but that course is not to be recommended, as it makes them too thin, unless the plates are made thick at the edges, which adds greatly to the first cost of the plates of which the pipes are manufactured.

Flanges made as shown in Fig. 57, of an angle-iron or steel-angles, welded into a ring, or rolled solid, vary according to the diameter of the pipe and thickness of the plates. They are riveted to the ends of the pipes.

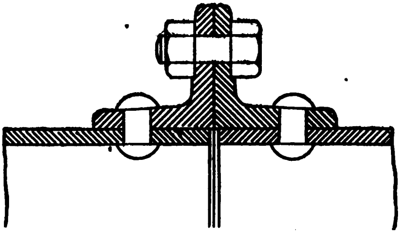

Fig. 57.

The wrought-iron flanges are always faced straight across. Again in some instances the angle-iron ring is screwed on to a short cylindrical ring riveted to the end of the pipe. This is illustrated in Fig. 58, in which *A* is the

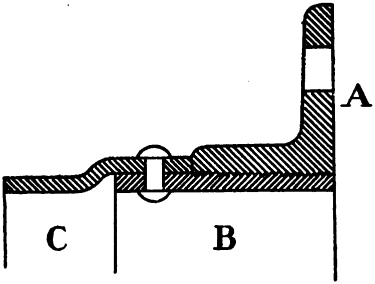

Fig. 58.

flange, *B* the ring, of such thickness that the diameter at the bottom of the thread is rather more than the outside diameter of the pipe; *C* is the end of the pipe.

Flanges are also stamped in dies and riveted to the ends of the pipes, as illustrated in Fig. 59. They are usually so truly cylindrical, and their faces so level, as

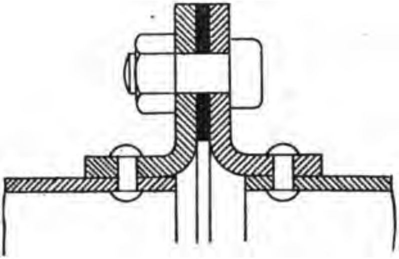

Fig. 59.

not to require facing, and the joints are made by an india-rubber ring.

A peculiar flange pipe-joint is illustrated in Fig. 60. It is recommended for tubes of small diameters. The ends, *A* and *B*, of the tubes are expanded and drawn

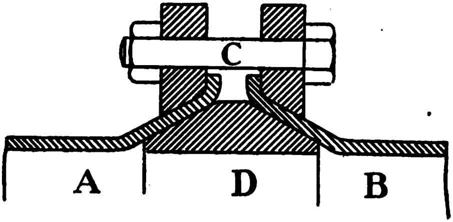

Fig. 60.

together by the bolts *C* and nuts, over a turned double cone *D*. It is a cheap and very advantageous method, because the joint can be quickly made, and the tube can be made very thin; but the loose flanges are inconvenient for shipment. This joint is also applicable for lead pipes.

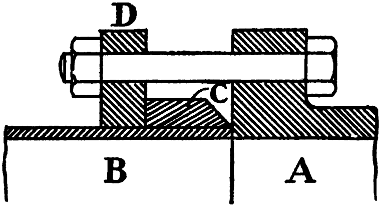

Fig. 61.

The joint illustrated in Fig. 61 is very suitable for small copper steam pipes, say up to about 4 inches diameter for high pressures. The flange *A* is the branch on the steam stop-valve; *B* is a copper pipe having a small collar *C* brazed on; and *D* is the flange on the copper pipe, placed on the pipe before the collar is secured. The copper collar, which is soft, is forced against the cast-iron flange by means of the bolts, and makes a perfectly tight joint.

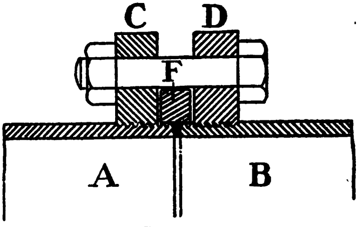

Fig. 62.

Another example of flange joint for small high-pressure steam pipes is illustrated in Fig. 62. *A* and *B* are the ends of the two pipes; *C* and *D* are stamped wrought-iron or steel flanges. Between the ends of the two pipes is placed a copper ring, with an outside cast-iron ring *F* between the flanges to keep it central; the joint being tightened up by bolts in the usual manner.

In the *American Machinery*, September 1896, is described Mr. George J. Rockwood's joint for high-pressure steam pipes. It states:—"One of the annoying details of the use of high-pressure steam is the question of pipe-joints, and many kinds of packings have been devised to overcome the difficulty. While some of these answer admirably, the question of metal to metal joint has been discussed, and attempted in various ways. Flanges have been screwed on the pipes and the joints formed on the flanges inside the bolt circle, but there is a tendency for the steam and moisture to work its way through the thread and give trouble, even when the ends of the pipes have been riveted over on the flanges." Mr. Rockwood's joint is illustrated in Fig. 63. It will be seen that the flanges *A* and *B*, which are very heavy castings, are

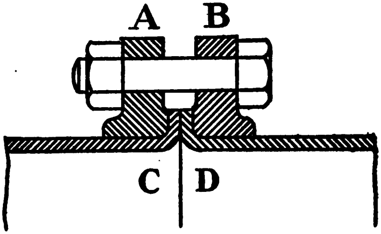

Fig. 63.

forced on the pipes *C* and *D* a sufficient distance to allow the end to be flanged over against the casting as shown. This is done more readily than could be imagined, and without injury to the metal. It would naturally be supposed that the correct method would be to make the inside corner of the casting an easy curve of large radius to avoid unnecessary strain on the pipes. This was done with the first ones, and nearly every pipe end split while being flanged. A short radius curve, just enough to round it over, is now used, and there is practically no trouble experienced in making the flanges. After flanging the faces of the pipes are faced off in a lathe, and when screwed together, by closely-pitched bolts, it makes a joint which is practically as solid as the pipe, and there is no packing to blow out. These joints have proved so successful that the Walworth Manufacturing Co., of Boston, Mass., have adopted this style of joint for pipes from 8 inches to 20 inches in diameter.

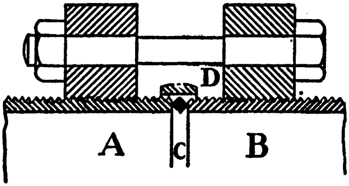

Fig. 64.

Willam's steam-pipe joint for heavy pressures is illustrated in Fig. 64. The pipe ends *A* and *B* are screwed, and have heavy flanges screwed upon them a short distance behind the end of the pipe. The beauty of this joint consists in that it can be made to take apart and put together again as often as is desired, and it is always absolutely steam-tight. The copper ring *C* is diamond-shaped in section, and the joint is surrounded outside by a cast-iron thimble *D* for convenience in getting the pipe ends together. The thimble is slipped back for getting at the joint, which is tightened up by a sufficient number of bolts through the flanges. All the faces of the pipe ends are turned quite flat.

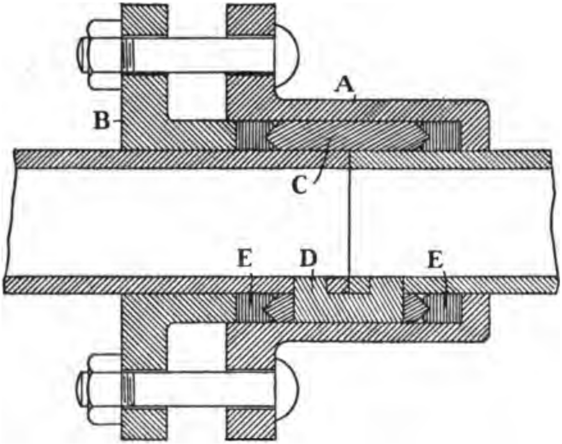

Fig. 65.

Howell and Littler's Patent Box-flanged Pipe-coupling.— This joint is specially suitable for all purposes where an efficient, safe, and durable coupling is required for either water, steam, hydraulic, or compressed air. As will be seen from section, Fig. 65, this joint consists of a stuffing-box *A*, and gland *B*, inside of which is placed the ring or ferrule *C*. The ferrule is pierced with slots to receive the cramps *D*, the ends of which also fit into corresponding holes in the ends of the pipes, and thus holds them in position. The ends of the ferrules are cone-shaped and are in contact with suitable packing rings *E* and *E*. When the gland is forced down upon the packing rings they are pressed against the coned ends of the ferrule and outside walls of pipe and walls of coupling-box, thereby ensuring a perfectly tight joint. There is a great advantage in this joint for export, because the couplings are loose and can be packed separate, hence the cost of shipment reduced and subsequent handling considerably facilitated. The joints, if leaky, can be repacked at any moment without interfering with the pipes, and as there are no recesses or hollows inside the pipe to cause dirt or sediment, the advantage of such an arrangement as this is obvious. The ends of the pipes being in perfect alignment ensures a perfectly clear way inside throughout the pipe.

Howell's Special Light Lap-welded Tubes with Improved Pipe-coupling.—These joints are suitable for steam, water, or compressed air. They differ from most other joints inasmuch as the joint itself is made outside the tubing, thus removing all risk of pieces of packing material being drawn into the valves, cock, etc. There is no screw to weaken the tubes or add to the cost. *A* and *B*, Fig. 66, are the two pipes furnished at the ends with small flanges or collars; *C* is a ring fitting on the outside of the small collars; these rings are forced against suitable packing fitted into the flanges *D* and *E*; the whole being secured together by the bolts.

The steam-pipe joint adopted at the City of London and the Metropolitan Electric Lighting Stations is illustrated in Fig. 67. The joint is made simply with a copper ring *A*, ⅛ of an inch thick. These rings are cut off the required thickness from a copper cylinder of the necessary size, and are carefully annealed. The joint is made between two butt ends *B* and *C* of wrought-iron steam pipes which have not got flanges welded on them, but only collars *D* and *E* welded on or screwed on and brazed, the former being by far the best; behind the collars are loose wrought-iron flanges, in which the bolt-holes have

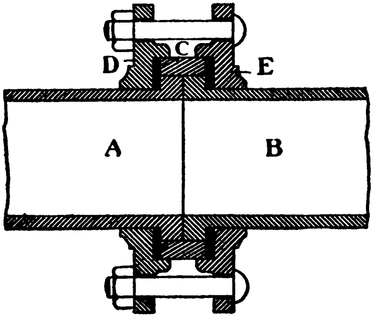

Fig. 66.

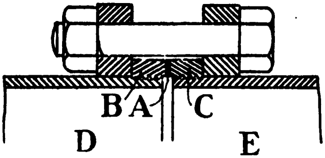

Fig. 67.

been drilled to templet before the collars on the pipe ends are fixed; the loose flanges facilitate adjustment in making the joint.

There is an endless variety of designs in hydraulic pipe joints, all having more or less merit. That shown in Fig. 68 is very good, but rather expensive. *A* and *B* are the two pipes having welded collars *C* and *D*; before the collars are secured to the pipes, the flanges *E* and *F* are pushed on. *G* is a soft brass or copper ring which fits on the collars, and leather washers *H* and *J* are placed between the ends of the pipes and the bottom of the recesses formed in each end of the ring. The whole is tightened up by bolts as shown.

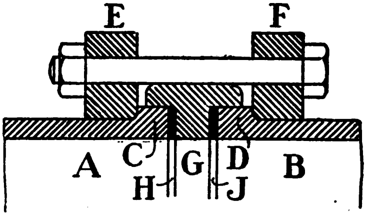

Fig. 68.

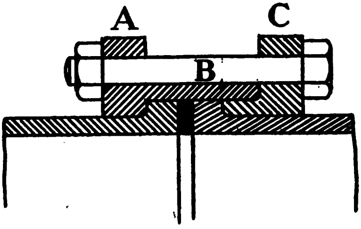

Fig. 69.

A more expensive joint is illustrated in Fig. 69, where the two pipes, as in the last example, are furnished with fixed collars; the leather washer is placed between the two pipe ends. The flange *A* is furnished with a long boss *B*, forming as it were a stuffing-box; the flange *C* has also a boss forming a gland. The two flanges are placed on their respective pipes before the collars are welded or screwed on. The whole joint is tightened up by the bolts.

A still more expensive example of hydraulic pipe joint is shown in section Fig. 70, where *A* and *B* are the two pipes provided with collars. *C* is a wrought-iron distance piece bored out at each end to fit the collars on the ends of the pipes, and forming stuffing-boxes, the flanges *D* and *E* acting as glands. The joints are made by leather washers, and screwed up by the collar-bolts or double-ended studs *F*, which are put into their place through slots in the distance piece.

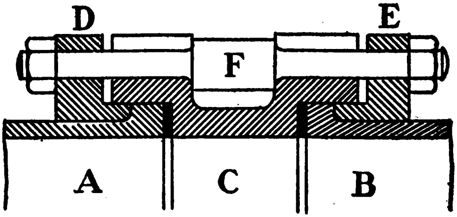

Fig. 70.

Messrs. Howell and Company of Sheffield manufacture pipes made of steel, iron, or other metals, with flanges forged from the solid tube, so that no welding, brazing, or screwing is necessary.

Joseph Aird's patent flanged tubes are illustrated in Figs. 71 and 72. In this case the tubes *A* and *B* are provided with collars, which are grooved so as to form a recess into which is placed a gutta-percha, lead, or asbestos ring, to suit the purpose for which the pipe is used. The flanges *C* and *D* are made in halves so that they can be placed on the tube over the collars, the two halves being held in position and prevented from slipping away from one another by the peculiar shape of the joint. The flanges are also made to fit one another in a similar way to a stuffing-box and gland.

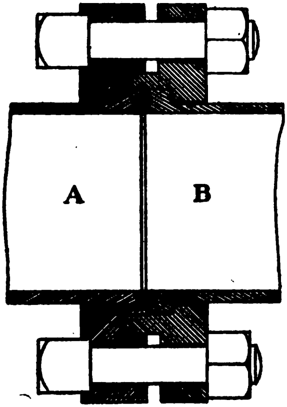

Fig. 71.

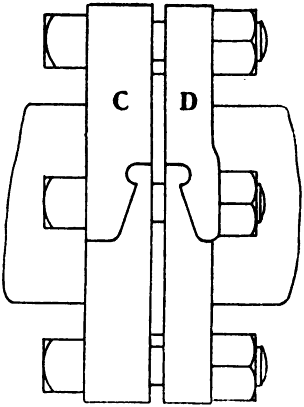

Fig. 72.

A. and J. Stewart and Mensies' joint is illustrated in Fig. 73. The ends of the pipes are flanged over, and the packing ring is placed between them. The flange *A* is bored out to fit over one pipe, and the other flange *B* is provided with a facing of the same diameter as the flange on the pipe. The whole is tightened up by the bolts.

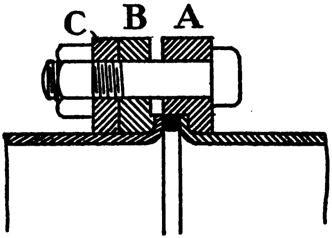

Fig. 73.

A wrought-iron ring *C* is placed on the back of the flange *B*, into which the bolts are screwed, the nuts on the bolts only acting as check nuts.

Lloyd and Lloyd's special joint for collieries, termed the "Albion" loose flange joint, is illustrated in Fig. 74.

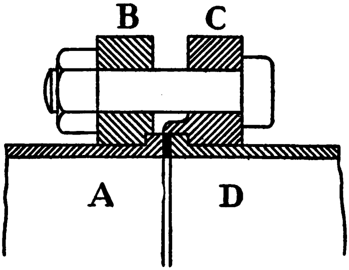

Fig. 74.

It is very similar in construction to the last described joint, except that there is no screwed ring, and that the end of the pipe *A* is slightly let into the flange *B*; there is also a recess in the flange *C* for the end of the pipe *D* and the jointing material, so as to keep the latter perfectly central with the pipe.

The flange joint illustrated in Fig. 75 is the one which has been adopted by James Eadie and Sons. The ends of the pipes are provided with shallow flanges, which fit into a deep recess in the flange *A*; flange *B* is provided with a long boss, which acts as a gland for the joint, the packing being placed between the ends of the pipe flanges. The flanges *A* and *B* are made of cast-iron, wrought-iron, or steel, according to the pressure in the pipe and the various engineers' fancy.

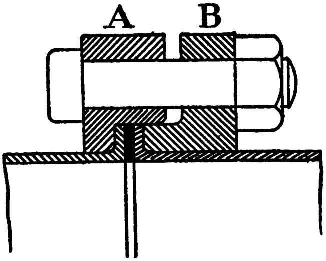

Fig. 75.

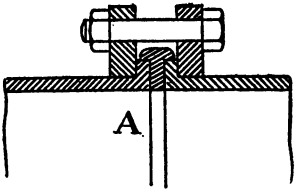

Fig. 76.

Lewis' patent "Acme" joint tubes are illustrated in Fig. 76. The two pipes are provided with collars at the ends, which fit in a recess on each side of a distance piece *A*, the flanges being flat round discs. If it is desired to deviate from a straight line the distance piece is made wedge-shaped, equal to the amount of deviation necessary.

Another joint manufactured by Edwin Lewis and Sons is shown in Fig. 77. It is intended for tubes for compressed air, water, or steam. It consists of a double cone ring *A*, on to which the cones on the ends of the pipes fit, and the flanges are drawn together by the bolts.

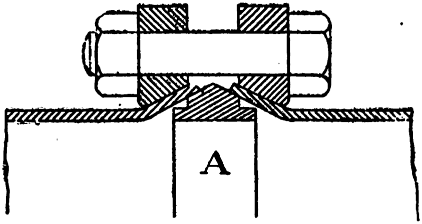

Fig. 77.

This makes a perfectly tight metal to metal joint if well made.

Wrought-iron Drain Pipes.

Wrought-iron drain pipes of large diameters are frequently provided with tight-fitting spigot and socket joints, as illustrated in Fig. 78. The spigot *A* and the socket *B* are made to fit one another closely, and of thicker plates than the pipes *C* and *D*, and riveted to the pipes. This joint was used for the storm outfall at

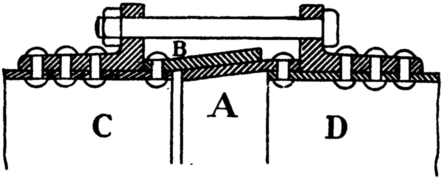

Fig. 78.

Bournemouth, the pipes being 36 inches in diameter. A modification of the above, in which hook-bolts are used, is shown in Fig. 79. The spigot *A* and socket *B* are made separate from the pipes; a flange *C* is placed on the pipe *D*, before the socket is riveted on, and the spigot is flanged over at *E* to allow the hooks *F* of the bolts to take hold of it. The spigot and socket are made to fit one another, as in Fig. 78.

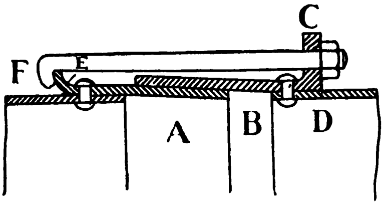

Fig. 79.

WROUGHT-IRON BALL-AND-SOCKET JOINTS.

Fig. 80 shows a section of a steel ball-and-socket joint, as used for the temporary steel line pipe laid on the bed of the river Mersey for the Vyrnwy water supply to Liverpool. *A* and *B* are the ends of the pipes, 12 inches

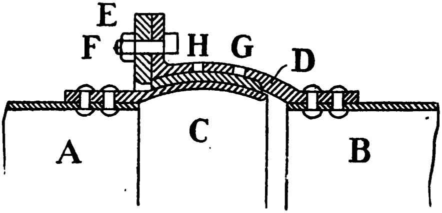

Fig. 80.

internal diameter, by $\frac{1}{4}$ of an inch thick; *C* is the ball and *D* the socket, each riveted securely to their respective pipes by two rows of rivets; *E* is a gland bolted to the socket by means of 14 steel bolts, 1$\frac{3}{4}$ inches diameter. It will be seen that the end of the socket nearest the gland is a little larger in diameter than the largest diameter of the ball, the latter having a radius of 7$\frac{3}{8}$ inches. The two pipes were placed in position, and lead run in through two holes as *G*, each $\frac{3}{4}$ of an inch diameter, and 1 inch apart. *H* is a vent-hole $\frac{3}{8}$ of an inch diameter. This makes an excellent ball-and-socket joint.

The ball-and-socket joint adopted by Alan Macdougall in the repairs to a submerged main, Toronto Waterworks, is shown in half sectional elevation, Fig. 81. The pipes were 6 feet in diameter, made of $\frac{1}{2}$ inch thick steel. The

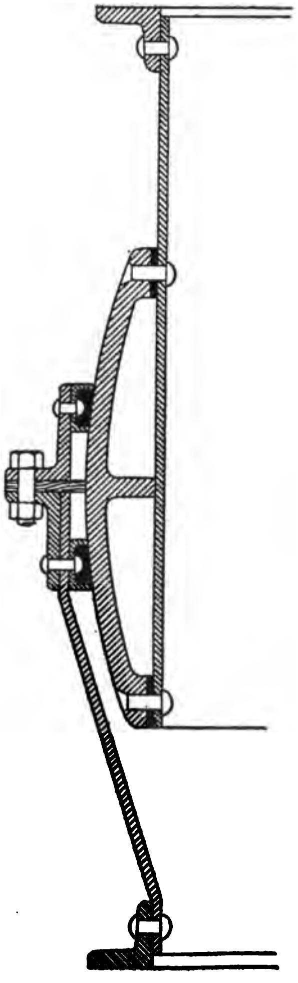

Fig. 81.

total length of the joint over the flanges was 5 feet, the flanges being made of 4 inches by 4 inches by 1 inch angle rings; the packing being made of lead secured in channel rings 3 inches by 1¾ inches × ⅜ of an inch, planed to suit the curve. The ball part was made of cast-iron 1¼ inches thick after turning, and secured on the spigot by ⅞ of an inch rivets countersunk on the outside. The stuffing-box was formed by two angle rings, one 6 inches by 4 inches by ⅝ of an inch, and one 6 inches by 3½ inches by ⅝ of an inch, with pine gasket ¾ of an inch thick between them, and securely held together by bolts 1 inch in diameter, about 6 inches pitch. This is probably the largest ball-and-socket joint ever made.

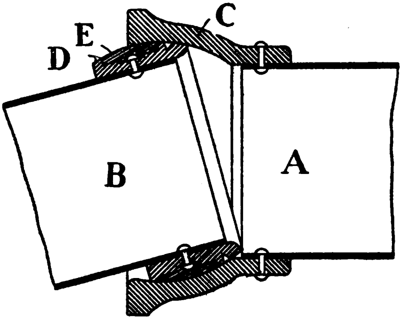

Fig. 82.

The flexible pipes or ball-and-socket joints have been largely used in United States of America. One very good and comparatively cheap design, adopted by the Risdon Iron Works, San Francisco, Cal., is illustrated in Fig. 82. *A* and *B* are the ends of the two pipes, *C* is a cast-iron socket riveted to the pipe *A* ; *D* is the ball riveted to the pipe *B*. It will be noticed that the ball itself will pass into the opening of the socket; after the ball has been inserted into the socket the white-metal *E* is run in. The illustration shows the ball-and-socket joint as it was constructed for joints in a double line of 16-inch diameter pipes, 16,000 feet long, laid across and under the Bay of San Francisco, between Dumbarton Point and Menlo Park, for the City Waterworks. The deepest part of the Bay at this point is over 50 feet, and the undertaking entailed considerable risk owing to strong tides and occasional heavy swells.

CHAPTER VIII

REMARKS ON WROUGHT-IRON PIPES

THE employment of wrought-iron and steel in the manufacture of pipes and pump trees has now become almost a standard practice. The lightness of wrought-iron and steel, as compared with cast-iron, is a great consideration, the freight and cost of transport in mountainous districts, as in Mexico for example, being greatly reduced.

On an average the weight required, as compared with cast-iron, is only ¼ to ⅕, and the pipes are constructed with only ⅓ the number of joints when placed in position; the latter consideration is of great importance, especially in long pipe lines.

Riveted wrought-iron or steel pipes up to 24 inches diameter can nest in suitability for shipment with a difference of 2 inches, large pipes with a difference of 3 inches; welded pipes can be nested with a difference in diameter of 1 inch.

Welded steel pipes are usually made in lengths of from 14 feet to 18 feet, riveted pipes 18 feet to 40 feet.

The joints in wrought-iron and steel pipes are tighter than in the case of cast-iron, because with wrought-iron the lead can be caulked more firmly, as there is then no danger of splitting the socket, and the risk of leakage is less on account of the smaller number of joints.

Rules for Thickness of Wrought-iron Pipes.

In calculating the thickness required for wrought-iron pipes the following rule may be used:—

$$T = \frac{0{\cdot}433 \times H \times R}{45{,}000};$$

in which T = thickness of metal

H = head of pressure in feet;

R = radius of pipe in inches;

45,000 = tenacity of wrought-iron in lbs. per square inch;

from which we get:—

$$T = 0{\cdot}0000096 \times H \times R.$$

For wrought-iron a factor of safety of six is sufficient; wherefore we obtain—

$$T = 0{\cdot}0000576 \times H \times R,$$

or, if we take the diameter D, instead of the radius R, we get—

$$T = \frac{0{\cdot}0000576}{2} \times H \times D = 0{\cdot}0000288 \times H \times D.$$

or,

If the pressure is given in lbs. per square inch the rule for thickness of wrought-iron pipes becomes—

$$T = 0{\cdot}0000665 \times P \times D,$$

in which = P = lbs. pressure per square inch.

Rule for Thickness of Welded Wrought-iron Steam Pipes.

(Board of Trade Rule.)

$$T = \frac{D \times P}{6000};$$

in which T = thickness of plate in fractions of an inch;
D = diameter of pipe in inches;
P = working pressure in lbs. per square inch.

Rule for Working Pressure of Welded Wrought-iron Steam Pipes.

$P = \frac{6000 \times T}{D}$ for pipes $\frac{1}{4}$ of an inch thick or more.

Rule for Weight of Wrought-iron Pipes.

$W = 2{\cdot}64\ (D^2 - d^2)$; or $2{\cdot}64\ (D + d) \times (D = d)$;
in which W = weight per lineal foot of pipes in lbs.;
D = external diameter of pipe in inches;
d = internal diameter of pipe in inches;
$2{\cdot}64$ = a constant.

Thickness of Steel Pipes.

It might naturally be expected that steel pipes should be made thinner than wrought-iron pipes in proportion to the greater tensile strength of steel. "Theoretically," says Mr. Samuel MacCarthy, "this should be so, but in practice it can only be carried out to a limited degree. Not only is a larger margin required for safety, but the exigencies of manufacture necessitate a certain thickness of plate to ensure making a sound weld; and the thickness cannot be reduced without risk."

Rule for Thickness of Brazed Copper Steam Pipes.

(Board of Trade Rule.)

$$T = \left(\frac{D \times P}{6000}\right) - \tfrac{1}{16};$$

in which T = thickness of plate in fractions of an inch;
D = diameter of pipe in inches;
P = working pressure in lbs. per square inch.

Rule for Working Pressure of Brazed Copper Steam Pipes.

$$P = \frac{6000 \times (T - \frac{1}{16})}{D}.$$

To find the Weight of Copper Pipes.

$W = 3{\cdot}03\,(D^2 - d^2)$; or $3{\cdot}03\,(D + d) \times (D - d)$;
in which W = weight per lineal foot of pipe in lbs.;
D = external diameter of pipe in inches;
d = internal diameter of pipe in inches;
$3{\cdot}03$ = a constant.

To find the Weight of Brass Pipes per lineal Foot.

$W = 2{\cdot}82\,(D^2 - d^2)$; or $2{\cdot}82\,(D + d) \times (D - d)$;
in which W = weight of pipe per lineal foot in lbs.;
D = external diameter of pipe in inches;
d = internal diameter of pipe in inches;
$2{\cdot}82$ = a constant.

CHAPTER IX

LEAD AND COMPOSITION PIPES

THE Romans, as we have before stated, had lead pipes made of long strips of sheet bent cylindrical and joined at the longitudinal seams. Haydn's *Dictionary of Dates* states that the lead pipes, for the conveyance of water, were brought into use in the year 1236—in what country is not stated. It is quite evident, however, that they had been used long before that date.

The pipes for the first London Waterworks were of lead, and the Works were built by a Dutchman, Mauris, in the year 1582.

Up to the year 1741 lead pipes, so far as we can trace, were made by hand, but in that year Mr. James Creed invented and patented a machine for their manufacture on a large scale. This machine cut the lead sheets up in strips, to the width required for the given diameter of pipe. These strips were turned into pipes by means of rollers; between the rollers was placed a ball, which produced the inside diameter of the pipe, and at the same time the edges were scraped fit for soldering by a tool fixed on the frame which held the ball.

Lead pipes were first rolled in the year 1791. In that year Mr. John Wilkinson, of Berwick-upon-Tweed, cast lead ingots in lengths, and put them on bars of iron, or of other material harder than lead. These bars or mandrils, as they are technically termed, he varied in length and diameter according to the size of pipe required. The mandril, with the lead ingot upon it, was extended to the length and thickness of the pipe manufactured; he passed repeatedly between the rollers with grooves of different sizes, according to the external diameter required. He also claimed the process of drawing the lead ingots through metal gauges or dies of different diameters after the lead had been placed on the mandril extended to the length and thickness desired. The mandril was then withdrawn, leaving a pipe of even diameter and thickness, and of uniform length.

One of the greatest—perhaps the greatest of all improvements in lead and composition pipes—was made by Mr. John Hague, in the year 1822, when he patented and introduced his solid pressing arrangement. The pipes manufactured upon this principle for gas and water supply services are now almost universally employed, especially for the former purpose. These pipes are forced out by means of hydraulic pressure through a die or core placed in the bottom of a cast-iron cylinder. Pipes of this description are much cheaper and much more reliable than those made of strips of sheet lead and soldered at the longitudinal seams, in fact Mr. Hague's patent completely revolutionized the lead pipe trade.

Knowledge of the deleterious effect of lead pipes upon potable water induced many chemists and other ingenious inventors to attempt improvements upon the ordinary pipes, and amongst these we find lead pipes lined with tin, which invention was secured by Royal Letters Patent by Mr. George Alderson on January 26, 1804.

LEAD PIPE JOINTS.

The most common method adopted in joining the different lengths of lead pipes, or securing cocks and valves to the same, is the ordinary wipe-joint illustrated in Fig. 83; but this is a joint very difficult to make well and neatly, except by first-class workmen.

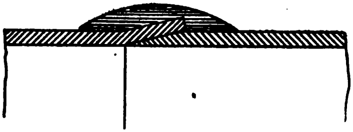

Fig. 83.

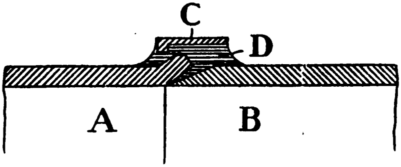

Fig. 84.

The form of joint shown in Fig. 84 can, however, be made by any fairly competent workman, and gives a first-class joint with very small amount of solder. *A* and *B* are the ends of the lead pipes to be joined. *C* is a turned ring of brass, steel, or other metal that cannot be fused by solder; *D* is the solder filling up the space between the lead pipe and the ring. Such joints have been carefully tested, and found to withstand a greater pressure than the pipe itself. The essential part of the joint is the brass ring *C*, which forms a support for the solder, and reduces the workman's task merely to wiping off the superfluous metal. The wiping rings are manufactured by Mr. Holt of Liverpool. For wiping, strong cotton bed-tick when old and soft is very good, but the best material is "fustian" or skin. The cloth requires to be well greased before using, but not too much, as it will make the joint look dirty when finished.

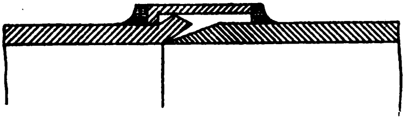

Fig. 85.

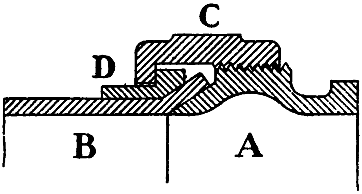

Fig. 86.

A modification of above joint, which requires still less solder, is illustrated in Fig. 85; it will be noticed that the solder is only required round each end of the ring.

Many methods have been adopted for connecting lead pipes to pumps and other machinery, but as all methods possess certain features in common we need only illustrate one example. This is illustrated in Fig. 86. In this case *A* is the casting to which the lead pipe *B* has to be connected. The casting is screwed on the outside and fitted with a nut *C*. There is a bush placed over the pipe and inside the nut. The outside of the casting *A* is coned at the end to fit the inside of the bush *D*, so that when the nut is tightened the lead pipe is coned and a tight joint is effected.

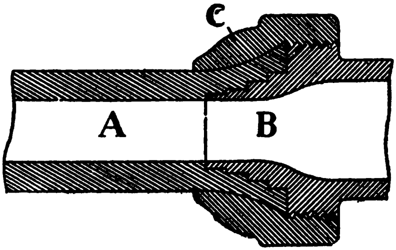

Fig. 87.

A patent "grooved" joint for fixing lead pipes without solder, manufactured by Messrs. J. Tylor & Sons, Ltd., London, is illustrated in section, Fig. 87. *A* is the lead pipe, *B* a taper brass piece, and *C* a brass nut. If the joint is to be made with a light pipe, place the diminishing lining into the nut *C*. If strong lead pipe is used it will not be required. Unscrew the brass nut *C*, and slip it over the end of the lead pipe. Swell out the end of the lead pipe by driving into it a taper piece of hard wood, the same taper as the piece *B*. Trim off the end of the lead pipe square, and having well greased the outside end of pipe to prevent it twisting, slip the nut *C* up to the swelled end. Hold firmly, and screw up the nut *C* with a spanner. It is not necessary to apply much force to the spanner, as the grooves of *B* immediately embed themselves in the lead pipe, each groove making a perfectly sound joint, which will sustain a pressure greatly in excess of that which the pipe itself will stand.

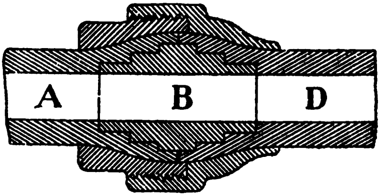

Fig. 88.

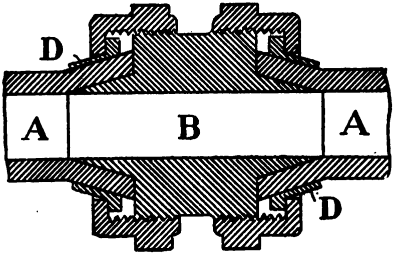

Fig. 89.

This joint as applied for coupling up plain lengths of lead pipe is shown in Fig. 88. In this example *A* and *D* are the lead pipes, *B* the taper piece, and *C* the brass nut.

Messrs. J. Brierly and S. Melling's lead pipe joint, manufactured by Messrs. Mather and Platt of Manchester, is illustrated in two forms in Figs. 89 and 90. Fig. 89 shows the joint adopted for coupling two lead pipes; Fig. 90 when a lead pipe has to be coupled to a wrought-iron one. In the former figure *B* is a brass coupling piece having sharp spigots at each end, which are forced into the ends of the two lead pipes. Before the ends of the pipes *A* and *A*, however, are forced on to the conical spigot, the conical ferrules *D* and *D*, along with the screwed couplings or nuts, are slipped on. These couplings screw on to the connecting piece *B*, and, as they are drawn together, the spigots are forced home at the same time that a pressure is exerted on the outside of the pipe at each end by the ferrule *D*.

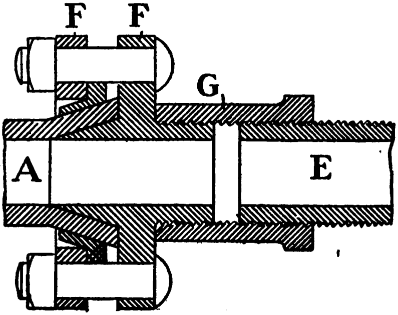

Fig. 90.

In Fig. 90, *E* is the iron pipe and *A* the lead pipe. As far as the latter is concerned, the joint is practically the same as that shown in Fig. 89, except that the taper spigot and ferrule are drawn together by means of bolts in the flanges *F* and *F'*; the iron-pipe *E* being united to the piece by means of the screwed sleeve *G*.

Rule for Thickness of Lead Pipes.

The thickness of lead pipe required to withstand a given pressure may be calculated by the following rule:—

$$T = \frac{0{\cdot}433 \times H \times R}{2745};$$

in which T = thickness of pipe in fractions of an inch.

H = head of pressure in feet;

R = radius of pipe in inches;

from which we get:—

$$T = 0{\cdot}0001578 \times H \times R;$$

for lead a factor of safety of 10 is required, hence the last rule becomes:—

$$T = 0{\cdot}001578 \times H \times R;$$

or, if we take D = the diameter of pipe in inches, instead of radius R, we get:—

$$T = 0{\cdot}000789 \times H \times R.$$

Weight of Lead Pipes.

$$W = 3{\cdot}86\,(D^2 - d^2);\ \text{or}\ 3{\cdot}86\,(D + d) \times (D - d);$$

in which W = weight of pipe per lineal foot in lbs.;

D = external diameter of pipe in inches;

d = internal diameter of pipe in inches;

$3{\cdot}86$ = a constant.

CHAPTER X

EARTHENWARE, STONEWARE, STONE, GLASS, AND CEMENT PIPES

THE first mention we have as regards antiquity of these classes of pipes, is that we have already mentioned in the introduction, of the waterworks of Sidon.

Coming down to more modern times, we find that John Etherington invented a machine for the purpose of making and casting—in clay—earthenware pipes for the conveyance of water in the year 1619.

William Edwards secured a patent for earthenware pipes in the year 1725. The title of the patent is "A new method never yet known or practised for making of pipes with clay or earth for the conveyance of water under ground from place to place." These pipes were made by placing a mandril of wood on a potter's wheel, and covering it with the required thickness of clay, afterwards the pipe was burned in a kiln.

Although stone pipes must have been very expensive and cumbersome to handle, we find that Bryan Morris patented, in the year 1720, a machine for boring stone, "in either a straight or circular direction or form for pipes, pumps, or other use;" and again, in the year 1734, John Taite secured a patent for making stone pipes.

Pipes made of stone were also patented, in the year 1798, by William Docker; he proposed to make pipes by boring out solid blocks of stone with different centre bits of the required diameter, which may be effected either by manual labour, or by engines made for the purpose, and when so bored the joints of the pipes or tubes must be "affixed together," which joints must be made so fine as not to admit of being cemented with a substance thicker than paint, in consequence of which the same will be equal to one solid or entire pipe.

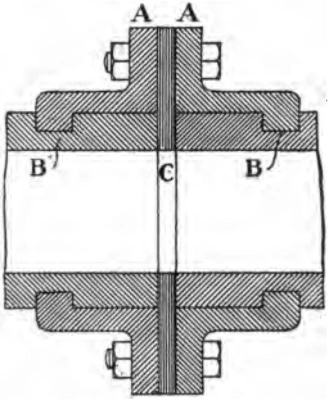

Fig. 91.

The manufacture of clay pipes by machinery was patented by Mr. George Johann Deyerlein, in the year 1810, in the specification of which patent he states:—"This invention consists of a box or receptacle into which clay is put, and then upon the clay a plunger or forcing instrument is made to act, by means of which the said clay is forced outward through suitable openings or orifices, which give the figure or form required to the expressed clay, suitable core being fitted into the orifice for moulding such pipes."

Glass pipes were first patented in the year 1845 by Freeman Roe. The pipes were joined by means of metal unions and cement, or they had metal collars attached to them and were then screwed together, or they had threads formed on them by moulding. The method of joining by metal unions and cement is very good, therefore we reproduce one of the many joints described. Fig. 91 is a longitudinal section, and Fig. 92 an end view of the two ends of the pipes united by means of the metal clip *A*, fitting into the grooves *B*, and enclosing the collar of soft and elastic material *C* between them. It will be evident

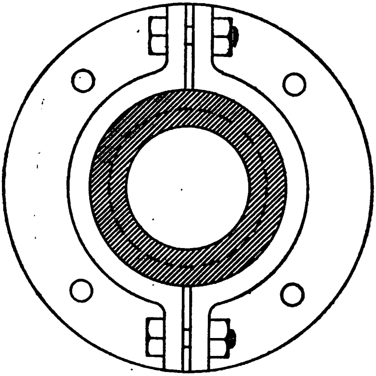

Fig. 92.

that the only preparation required on the ends of the pipes is the formation of the grooves *B* to receive the corresponding projections on the clips *A*, and thereby furnish a hold for the same. In this instance the clips are made in four pieces.

EARTHENWARE, STONEWARE, STONE, GLASS, AND CEMENT PIPE-JOINTS

The spigot-and-socket is the usual joint for this class of pipe, and the joint itself is made by well-puddled clay driven in by a tool, and for additional security clay should be puddled round the outside of the joint. Cement is sometimes used when any water is met with; it is a good plan to force a ring of tarred gaskin into the bottom of the socket before the clay or cement is introduced. The objection to the ordinary socket is that when the sewer has to be examined several lengths must be taken up or one length broken; to prevent this, several plans have been tried and many patented. One arrangement is illustrated in Fig. 93, which consists of an ordinary socket pipe in which the upper half of the socket is removed, which admits of any single length being removed without disturbing its neighbour.

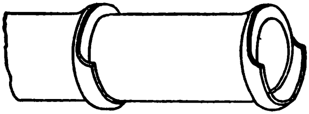

Fig. 93.

There is another method which consists of plain pipes, both ends having spigots, the sockets being made in halves and independent of the pipes. This is illustrated in Fig. 94. The inventor gives the following description:—"They are plain at both ends and are laid in chairs similar to the metals of a railway, each pipe being kept 6, 9, or 12 inches apart according to their diameter. The pipes being bedded in the chairs renders the disturbance of ground under the pipes to make the joints—as at present—unnecessary, and the top part of the chair—which for distinction is called a saddle-piece—being the last fixed, enables the workmen and superintendent to see that the pipes are properly laid and fairly jointed. In case of stoppage the saddle is easily removed without in any way disturbing the invert or general drain, and the pipes being some distance apart the state of the drain can be easily ascertained."

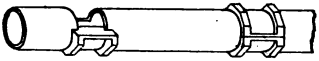

Fig. 94.

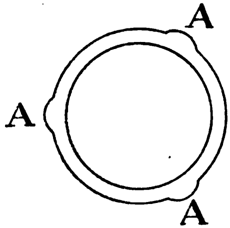

Fig. 95.

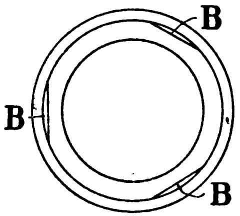

Fig. 96.

Mr. Botham's joint for earthenware pipes is illustrated in Figs. 95 and 96. The object of this joint is to keep the spigot concentric with the socket. *A*, *A* and *A* are three lugs on the spigot end of the pipe, as shown in Fig. 95, and the socket has three corresponding projections *B*, shown in Fig. 96; the spigot is inserted into the socket so that its projections lie with the projections of the socket, and then turned round until the projections on spigot and socket are brought in contact.

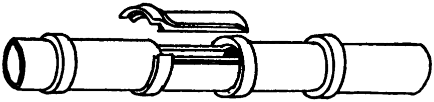

Fig. 97.

Capped earthenware and stoneware pipes have frequently been used; one form of this class is illustrated in Fig. 97. Holes are made in the barrel of the pipe, these being covered with caps.

Doulton's "Opercular" pipe is shown in elevation Fig. 98, and cross-section Fig. 99.

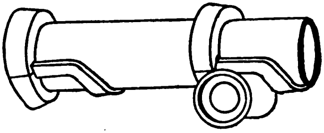

Fig. 98.

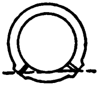

Fig. 99.

Sykes' new patent pipe joint is illustrated in Figs. 100 and 101. Fig. 100 shows sections of the ends of the pipes before jointing, and Fig. 101 after jointing. The joint is made by placing a thin fillet of grease on the black composition in the socket *A*, care being taken that it is uniformly placed round; a similar fillet of clay is placed on the rim, as shown at *B*, but will require more clay than grease. The clay must be well worked, so as not to be too stiff. The pipes having thus been prepared, they can be pushed home, great care being exercised in seeing that the pipe is thoroughly home, and that the clay is compressed; this can be more readily done by placing a chock against the end of the socket and slightly tapping it with a hammer. The joint is made by pouring thick liquid cement grout into the holes *C*, a small piece of clay should be placed between the two holes to prevent the grout going down both sides at once. By pouring the

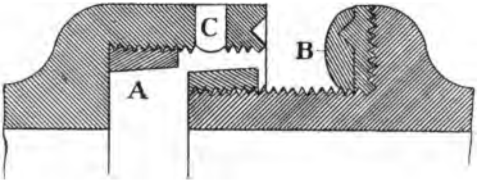

Fig. 100.

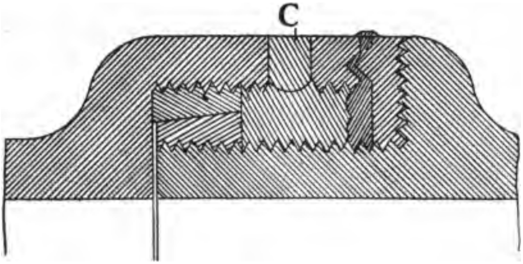

Fig. 101.

grout in one side and rising up the other will indicate that the grout has completed the circuit, and the joint properly made. A cup made of clay can be advantageously used for directing the grout into the hole.

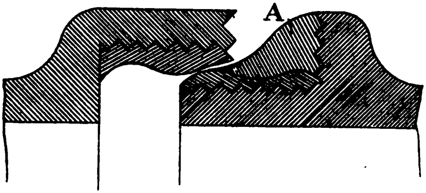

Fig. 102.

The pipes are usually laid by keeping about twelve in advance of the grouting.

Sykes' patent screw joint is made by compressing a patent composition shown at *A*, Figs. 102 and 103, which is a thick plastic cement which sets in water; it cannot run into the pipe and cause stoppages as in grouting; it

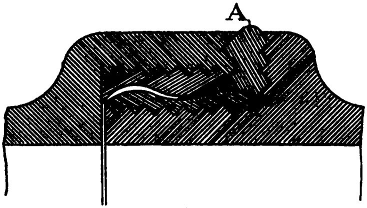

Fig. 103.

is impervious and imperishable. Fig. 102 shows the pipes before jointing. The composition is made by mixing the fluid—obtained from the makers, the "Albion Clay Company," Woodville—with Portland cement until a thick mastic is obtained of about the consistency of glazier's putty; as the composition sets quickly, it should only be made in small quantities.

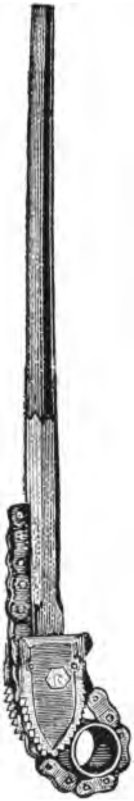

Fig. 104.

The mastic is placed round the rim of the pipes as shown at *A*, care being taken that it is evenly placed round; the pipe is then ready for laying, which can be partly screwed home by hand labour; but to thoroughly screw the pipe home, chain tongs, specially manufactured by the maker of the pipes, must be used; these tongs can be more readily used by allowing them to rest by the side of the cutting and the chain at the bottom, so that the pipe can be laid over the chain, and by pulling the chain over and dropping into the slot a grip can be obtained and the pipes screwed home. These pipes are made of the Albion Clay Company's "Granite Stoneware."

Another chain pipe wrench, which has been introduced in the market under the name of the "Vulcan" wrench, is illustrated in Fig. 104. These wrenches are very strong and durable, being made wholly from wrought-steel. The jaws are of saw temper; the teeth can be sharpened by filing only.

To change the chain, unscrew one cap-screw, but remove neither jaw; slip up the internal pin on which the chain swings, thus releasing the chain insert new chain, replace pin and cap-screw, screwing the latter firmly into place.

These wrenches are made either with flat-link chains, as illustrated, which are hand-made from steel prepared expressly for them, and with cable chains of finest quality. The chain swings from the centre, and can be used on either side the jaws.

The wrenches fit a range of sizes equal to six pairs of common tongs, and will outwear several pairs of any kind.

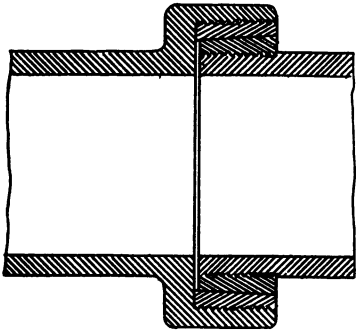

Fig. 105.

Stanford Pipe-joint.—The original joint of this pipe is illustrated in Fig. 105; it is suitable for every description of sewerage work, and the joint may be completed with Portland cement according to the nature of the work. The improved Stanford joint shown in Fig. 106 is self-centering, and thus ensuring perfect alignment of invert, there being no ledges at the joints to obstruct the flow of the sewage. This pipe is so constructed as to allow a slight settlement of the ground without in any way injuring the joint, but should a firm and ridged joint be required, it can be so made by finishing off with Portland cement.

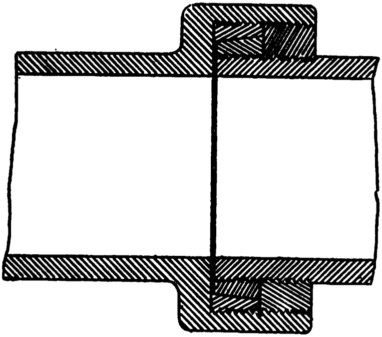

Fig. 106.

It is advisable to apply a little grease to the joint before laying, to act as a lubricant and ensure the pipe going home easily.

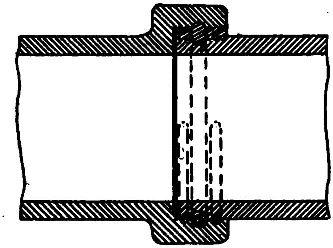

Fig. 107.

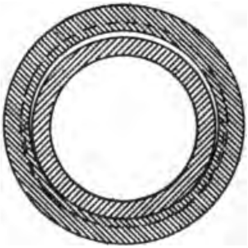

Fig. 108.

Patent "Paragon" Pipe-joint.—The stoneware drain-pipes, with patent paragon joints, are manufactured also by the Albion Clay Company. This joint is illustrated in section, Fig. 107, and end view, Fig 108. It is made in three forms to suit the requirement of effective sewerage and drainage, at the least possible rate, in first cost and maintenance. It will be noticed in the illustration that the socket and spigot are screwed or furnished with circular grooves for holding the cement and eccentric with the bore of the pipe, so that the bottom line of the pipe is level when the spigot rests on the bottom of the socket, so that there cannot be any obstructive ledges at the joints; hence the solids are carried to the outfall without the necessity of excessive flushing, which wastes much water and floods the outfall, and destroys the manurial value of the sewage. To allow a joint to be made on the underside of the spigot eccentric, grooves are made in the spigot commencing from the centre line of the pipe, so that any cement or any other jointing material adopted, when run in will flow into the grooves and all round the spigot end of the pipe.

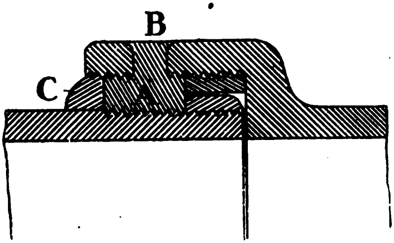

Fig. 109.

Hassel's Patent Safety-pipe.—The single-line Hassel's joint is illustrated in section, Fig. 109. This joint may be relied on where the ground is good and much subsoil water is not met with, but if the reverse is experienced, the double-lined joint, shown in Fig. 110, is to be recommended.

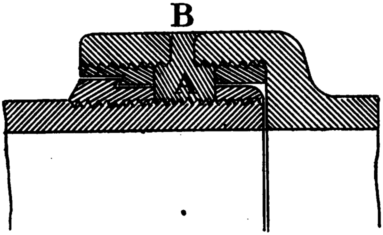

Fig. 110.

The cement *A* is run through the hole *B*, in the usual manner. When the single line is adopted a fillet of clay *C*, Fig. 109, must be put round the face of the socket till the cement has set.

This joint has been adapted by H. W. Department. These pipes can be had from Messrs. John Wragg and Son, 39 Victoria Street, London, S.W.

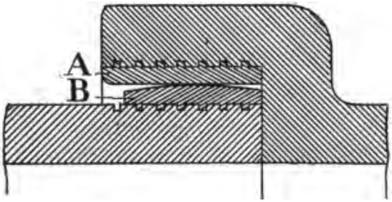

Fig. 111.

Doulton's patent self-adjusting joint for drain pipes, in which no cement is required, is shown in section, Fig. 111. In sewer work, in bad or wet ground, just where sound joints are required, the difficulty of making it is the greatest. In this pipe a tight joint is attainable by casting upon the spigot and in the socket of each pipe, by means of moulds prepared for the purpose, rings *A* and *B*, of cheap and durable material, which, when put together, fit mechanically into each other; and by making these rings of a spherical form, a certain amount of movement or settlement may take place without destroying the accuracy of the joint.

In laying these pipes, therefore, all that is necessary is to insert the spigot of one fairly and firmly into the socket of the one previously laid, the joint surfaces having previously been smeared with some kind of grease.

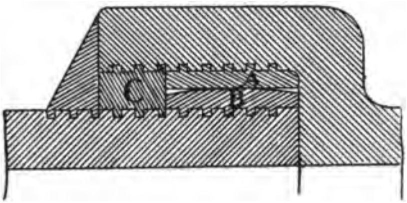

Fig. 112.

Doulton's patent "Composite Joint" is illustrated in Fig. 112; in it the composition joint *A* and *B* centres the pipes while the cement joint *C* is made. There is no possibility of cement entering the pipe to cause obstructions.

Fitzpatrick's patent drain pipe, manufactured by Messrs. Craig of Kilmarnock, is illustrated in sectional elevation, Fig. 113. In ordinary drain pipes, when the spigot end is inserted in the faucet of the adjoining pipe, the annular space is, according to the present practice, first filled up with "gaskin," for the two-fold purpose of securing a uniformity of bore, and preventing the cement entering the pipes; then the joint is padded round with cement. In thus sealing the joint, considerable difficulty is experienced in preserving continuity of level, and also in padding that section of the circumference which lies on the ground. There is also the danger of the cement settling, or running down to the bottom, falling away from the top and sides and causing an imperfect joint.

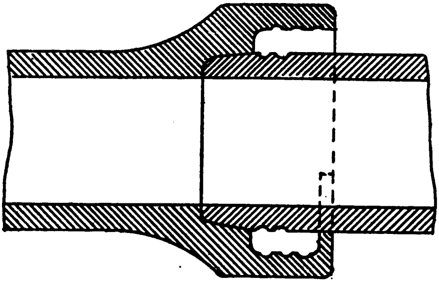

Fig. 113.

These objections are surmounted by the Fitzpatrick's patent joint. It will be noticed, by referring to the illustration, that immediately the spigot end of one pipe is inserted in the socket end of another, a perfect uniformity of bore is established without the use of gaskin. It is also evident that the manipulation of the joint is considerably facilitated, and that the cement can be more readily and securely introduced, especially around the lower section of socket, since the lip or raised edge forms an enclosed area, into which the cement can be packed with care, free of all obstructions, before the spigot end of the next pipe is inserted at all.

Corrugated Socket Stoneware Drain-pipes.—This socket has been patented by Mr. Arthur Wakefield of Victoria Street, London, S.W., and is manufactured by Messrs. Thomas Wragg & Sons. Fig. 114 is a front view of socket; Fig. 115, a section on line *A, A*; and Fig. 116, a section on line *B, B*. To make the joint:—On the shoulder of the socket place a band of mastic clay, then insert the spigot of the next pipe, taking care that the corrugations are always at the bottom, so as to be in position to receive the next pipe, and put a band of clay round

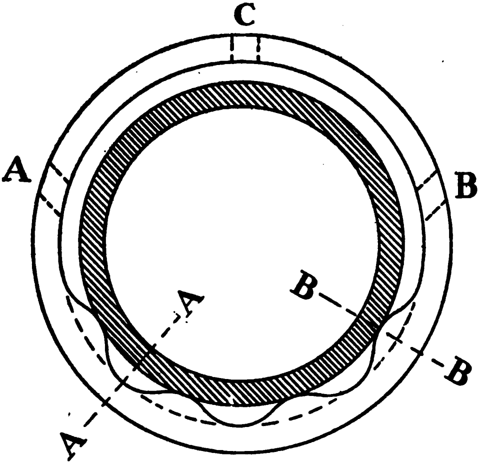

Fig. 114.

the mouth of the socket, pour neat Portland cement grout through hole *A*, till it appears at hole *B*, then leave it for a few minutes; in the interval other joints can be dealt with in the same way, by which time the cement first run will be sufficiently set as to receive the remainder without fear of bursting out the clay backing. Pour gently through hole *C*, till the crown portion of the joint is completed. Pull the clay out a little at this point so as to create an air vent. The depth of the sockets for these pipes is very great; pipes 4 and 6 inches diameter have sockets 2½ inches deep; 7, 8, 9, 10 and 12-inch pipes 3 inches; 16, 18, 21, 24, 27 and 30-inch pipes 3½ inch depth of sockets.

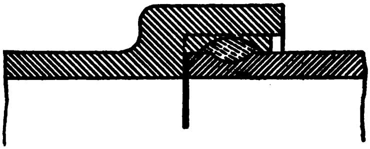

Fig. 115.

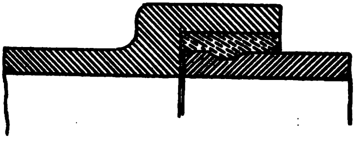

Fig. 116.

To obtain the band of mastic clay for the shoulder of the socket, place a plank, as shown in Fig. 117, on two pipes so as to form a table; on this plank nail two strips of wood varying from ¼ to ½ an inch in thickness according to the size of pipe to be laid—for instance, ¼ an inch thick for a 9-inch pipe, and ½ an inch for a 24-inch—with planed surface, the width apart to correspond with the width of the shoulder on the socket of the pipe to be joined. Into the groove so formed press mastic clay, dress off all the superfluous clay with a piece of wood or hoop-iron. Remove the clay from the groove with a piece of wood cut to the shape of a chisel, as illustrated in Fig. 118, and the width of the groove; the clay will come out in the form of a coil ready to lay on the shoulder of the pipe of uniform width and thickness.

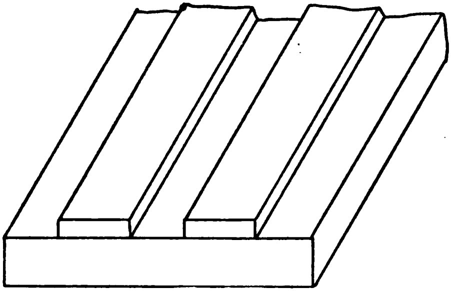

Fig. 117.

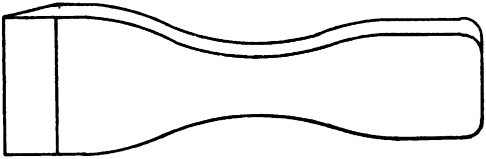

Fig. 118.

Although these pipes are comparatively a new invention they have met with a great success; as a proof of this we may say that they have been specified for the Newmarket drainage, which will have a length of 16 miles. One thousand pipes 18 inches bore have been ordered as a trial for the Bridge-end drainage, which will, when finished, be 5 miles in length.

Ames and Crosta's Patent Self-adjusting Joints.—There are two types of these joints, namely:—The single seal, and the double seal. The single seal is illustrated in section, Fig. 119, and end view, Fig. 120. When jointing these pipes, the sealing-chamber at the seat of the socket should be filled with clay, plastic cement, or other jointing material used; the spigot should then be forced home into the sealing-chamber; the displaced jointing material will be forced into the jointing space, overlapping the end of the spigot, and filling in the grooves on the spigot, thus forming a perfect seal of the socket; a fillet of the

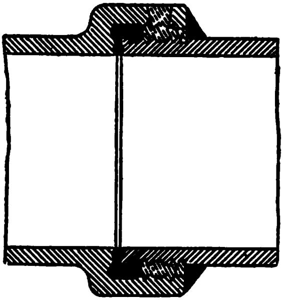

Fig. 119.

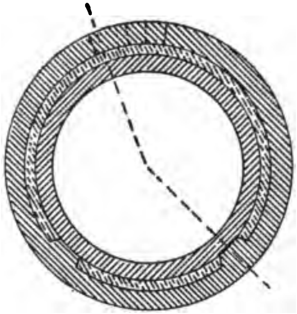

Fig. 120.

same jointing material should be worked round the entrance of the socket, the joint may then be grouted up through the running holes with running cement. If desired, liquid cement may be dispensed with, and the joint made in the ordinary way with stiff cement or clay.

The double seal joint is shown in section, Fig. 121. In making this joint, which is specially designed for water-logged ground, the sealing-chambers at the seat of the socket, and in the collar on the spigot, should be

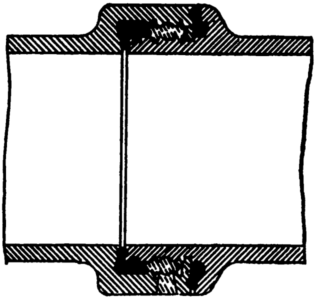

Fig. 121.

filled with suitable stiff jointing material and the spigot forced home; a perfect seal will thus be formed at each end of the joint. The cavity between the seals can then be grouted up with liquid cement.

Place's Patent Lock-joint.—The difficulty with many joints for sanitary pipes is to keep the spigot end of the pipe tight home in the socket while the pipe is being bedded, and this can only be insured when skilled workmen are employed. This difficulty is entirely obviated by Place's patent joint, shown in sectional elevation, Fig. 122, and end view, Fig. 123, for when the spigot is placed in the socket; and a small wedge inserted at the top of socket to keep the pipe in position, the spigot end cannot possibly be drawn, while at the same time the joint retains a certain amount of elasticity.

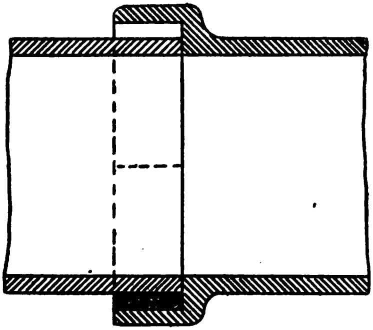

Fig. 122.

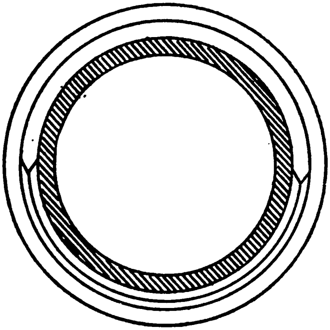

Fig. 123.

In referring to the illustration it will be noticed that the composition joint is only placed in the lower half of the pipe, and is of the shape shown in longitudinal section, Fig. 122, so that when it is in position it locks itself. The composition joints are painted with tar, tallow, or other suitable material, and lifted into position; a small wedge is driven between the top of the spigot and the socket (as already mentioned), thus making the lower half of the socket perfectly water-tight. The joint still retaining a certain amount of elasticity, it can be settled into its required position, and the top half of the joint made in the usual way with clay, cement, or other suitable material. These pipes are manufactured by Messrs. Joseph Place & Sons, Darwen.

Sutton's Flush-joint Pipe.—Fig. 124 is a sectional elevation; Fig. 125, end view of a spigot end; Fig. 126

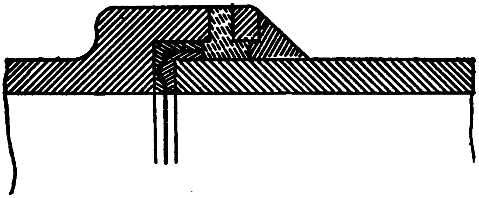

Fig. 124.

enlarged section showing spigot through the line *AB* fitting socket; and Fig. 127 enlarged section showing spigot through *CD*, of the single seal joint; the double seal joint is illustrated in sectional elevation, Fig. 128. Owing to inequalities in manufacture of sewage pipes, it is a well-known impossibility to depend upon the spigot of one pipe, and the base of the socket of the other, touching at all points in their circumference; this difficulty has been overcome by the Sutton joint, a continuity of invert is at the same time secured. These improvements are of great importance, as by its means a maximum flow of sewage is secured in the pipes, which is not interfered with, or broken up by the eddying caused through the space left open between the bottom of the socket and end of spigot. Owing to the bead on the end of the spigot being made to a smaller radius

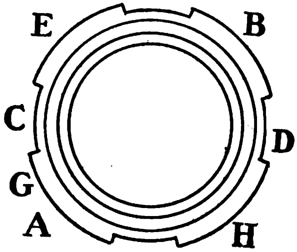

Fig. 125.

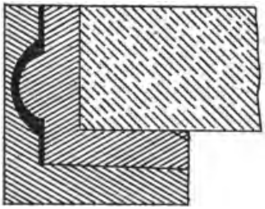

Fig. 126.

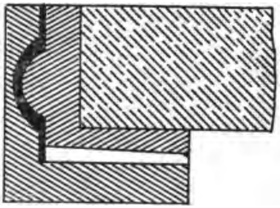

Fig. 127.

than the annular recess on the base of the socket, any carelessness on the part of the workmen in preparing these pipes with mastic is counteracted by the distribution, by squeezing of the mastic out of the annular recess by the bead, thereby causing the united surfaces to be entirely water-tight, and if not, the leakage of the cement is immediately detected by the workmen being unable to run the joint. The fact of the mastic being at right angles instead of parallel to the face of the joint, as in other pipe joints, makes it very difficult for the cement to force a passage through. The mastic is placed in one position only, viz. on the base of the socket; this means that the security of one joint only is necessary, instead of more than one, as in other cases. The inner lining in being returned round the end of the spigot is intended to merely guide the pipe when being driven home, at the same time centralizes it to guide the bead into the annular recess, but performs no other service. It is not continuous, and gives contact only at four points in the circumference, as shown at *E*, *G*, *H*, and *B*.

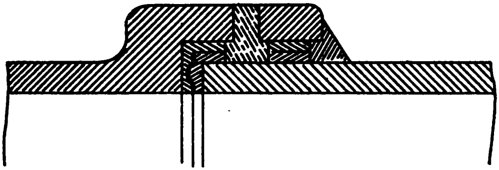

Fig. 128.

In the case of the double seal pipe, the outer rings are made with very much less play between them than is usually the case, so that they are almost in contact without any addition of mastic or other material. They are also placed so that they lie back from the end of the socket to allow a recess or space in which clay, greased hemp, mastic, or any other material, can be poured, making an absolutely secure joint against the entrance of water.

After having made and jointed the pipe, cement is poured into the annular space by the usual means.

CEMENT PIPES.

On the continent we frequently find sewage pipes made of Portland cement; there are instances in which pipes have been found perfectly sound after twenty years constant use; they improve in strength every year, and as a mark of strength it might be mentioned that they have been in several places used under railway embankments.

The German cement pipes are of the socket type, made in sizes varying from 12 inches upwards, and the thickness varying according to the diameter, pipes 15 to 18 inches in diameter being made about 2 inches thick. They are made in 5-feet lengths.

Sidero Cement Pipes.—This type of pipe consists of a steel coil made of bars of *H*-section, about $\frac{5}{8}$ of an inch deep, covered on the outside and lined on the inside with cement, or more properly cement mortar, for the composition is two parts, by measure, of sand to one part of Portland cement. These pipes have been used for a few years for water-mains subject to light pressures. They have been used for town supply in Venice and in Algeria, and for the water supply of the barracks at Maison's, Alford in Paris, in each case by French engineers, who report favourably upon it. They can be made to stand, when new, working pressures of 100 feet or more, and if laid underground the cement will no doubt continue in a good state of preservation so long as the steel of the coils is not attacked by corrosion. Two of these pipes were tested by Professor Unwin, and a short piece for special examination and prolonged test. The internal diameter of these pipes was about 19·68 inches, and the length about 9·84 feet.

The leakage of the two pipes, when subjected to a steady head of water of about 20 feet, was very considerable, and nearly identical, but the leakage decreased rapidly at first, and more slowly afterwards. With one of the pipes, the test was continued for eighty days, during which time the pressure was changed from 20 to 40, and finally 50 feet.

REMARKS ON EARTHENWARE, STONEWARE, STONE, GLASS, AND CEMENT PIPES.

Earthenware and stoneware pipes are in some places made from broken pottery, in others from gault clay, and sometimes the material is clay such as they use in the manufacture of Staffordshire bricks. The tensile strength of these pipes naturally varies greatly, according to the quality of the material of which they are made. Mr. Baldwin Latham showed by experiments that their capability of withstanding internal pressure might vary from 21·4 to 429·5 lbs. pressure per square inch of section.

Sir J. W. Bazalgette has proved, however, that their power of resisting a crushing force is much less variable than their resistance to tensile strain.

Mr. Baldwin Latham says that pipes when laid, and acting as a sewer, are always more or less exposed to the crushing action of the superincumbent earth, therefore they may be made of sufficient thickness to resist the pressure likely to be brought upon them. Sewer pipes of the thickness given in Table No. XXX, are sufficiently strong for all practical purposes, but when laid in deep cuttings in treacherous earth the thickness should be slightly increased.

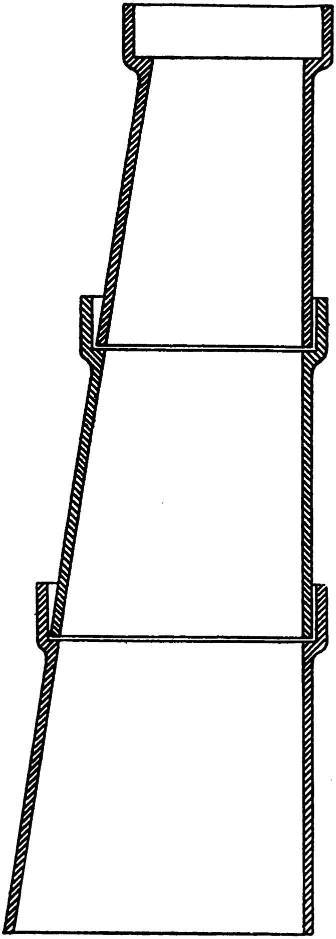

Fig. 129.

The thickness of fire-clay pipes should be greater than that of the best stoneware and earthenware pipes. With the latter, Mr. J. Bailey Denton states, the thickness should never be less than one-twelfth of the internal diameter. In the small sizes the proportion must be increased. A 4-inch pipe, for instance, should be at least ½ inch thick, while a good 18-inch pipe need not be more than 1½ inches thick.

The depth of the socket should increase with the diameter of the pipe, nothing less than 1½ inches being sufficient in the smaller pipes, and something more than 2 inches being desirable when the diameter exceeds 12 inches.

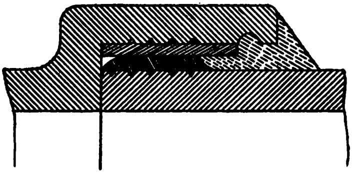

Fig. 130.

When calculating long lengths of pipes of this class of pipes, the column of length in work-feet in Table No. XXX will be found very handy, as the number in the column has only to be divided into the total length of pipe line, and the number of pipes is given.

It is very important in sewage pipes that the invert should be quite level; this is very different in the ordinary sewage pipes when they are tapered. This has, however, been overcome by the Albion Clay Company's taper pipe, illustrated in Fig. 129.

Cliff's double seal pipe-joint, as used for drains, is illustrated in Fig. 130. These pipes are similar to the Stanford jointed pipes, but have in addition a deeper and undercut socket, so that, after the pipe has been laid and tested, an ordinary cement joint can be made in addition to the Stanford joint.

CHAPTER XI

SWIVEL PIPE JOINTS

In many instances it is advisable, if not imperative, that there should be, at some place or another, a swivel joint,

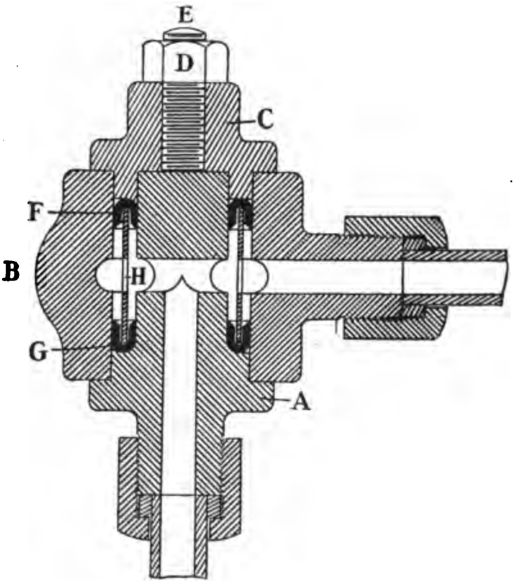

Fig. 131.

as, for instance, at the top or bottom of the upright centre post of jib and derrick cranes, when they are worked by steam or hydraulic power. They are also applicable to connect certain parts of moving machinery, which are actuated by steam, compressed air, water, or any other fluid, liquid, or gas; or in exhaust-pipes for such machines.

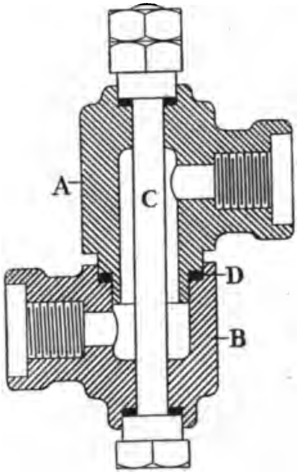

Fig. 132.

A swivel joint adapted for the top of the post of an hydraulic jib-crane is illustrated in sectional elevation, Fig. 131. It consists of three castings: *A* is connected to the crane post direct or through a pipe; *B* is the swivelling part which is connected to a pipe by an ordinary screw union; and *C* is a cap which is tightened up to its work by the nut *D*, screwed on to the stud *E*, which latter is either made in one with the casting *A*, for small swivels, or secured to it in large work. The swivelling part *B* is chambered out at the centre to allow the water to circulate freely round the plug *A*, and thus enter the hole that is drilled through it, leading to the central outlet, or communicating passage. To make the joint water-tight two ordinary U-shaped leathers *F* and *G* are secured, one in the recess near the bottom of casting *B*, and one the same distance from the top of the same casting; a perforated pipe *H* is placed between the two U-leathers to keep them in their places when no pressure is in the interior of the joint. This joint must be made either of gun-metal, or the working parts bushed and covered with gun-metal.

Another, although not as good arrangement, is illustrated in sectional elevation, Fig. 132. It consists of two castings, *A* and *B*, which are held firmly together by a strong centre bolt *C*. The casting *A* fits into the casting *B*, and the water-tight joint is made by a flat leather washer, *D*. There is also a washer under the head and nut of the centre bolt, *C*, to prevent leakage round it. The screwed branches are for connecting up the inlet and outlet pipes, to and from the crane or other hydraulic machine.

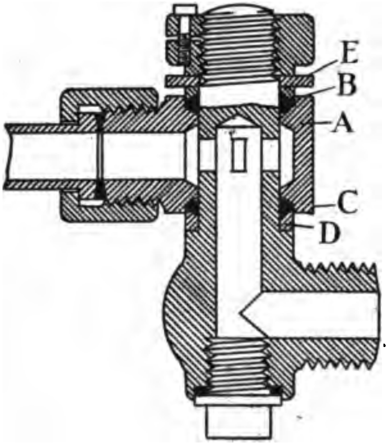

Fig. 133.

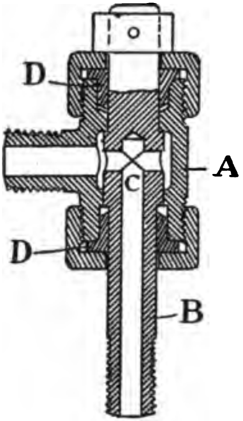

Fig. 134.

A modification of the last joint described is illustrated in sectional elevation, Fig. 133; it is furnished with plain leather washers instead of **U**-leathers; a shallow stuffing-box being provided at each end of the swivelling piece *A*, in which are introduced the leather washers, *B* and *C*,

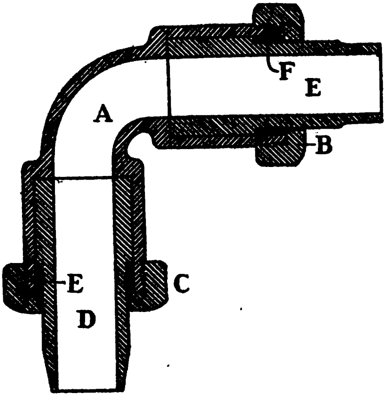

Fig. 135.

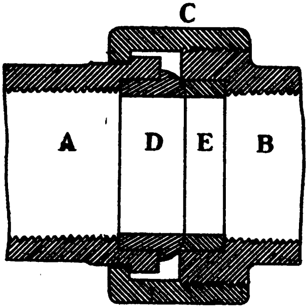

Fig. 136.

and the rings *B* and *E*, from the glands. The glands are secured to the piece *A* by means of small pegs, so that they turn with the swivelling piece. The whole is tightened up by the lock nut.

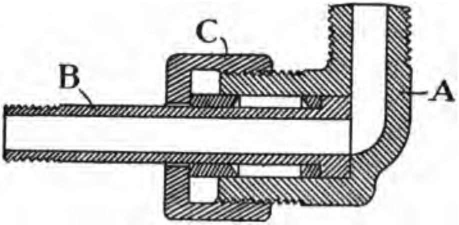

Fig. 137.

If hat-leathers should be preferred, the arrangement illustrated in Fig. 134 may be adopted, when it is suitable for 3 to 4 tons pressure per square inch. *A* is the

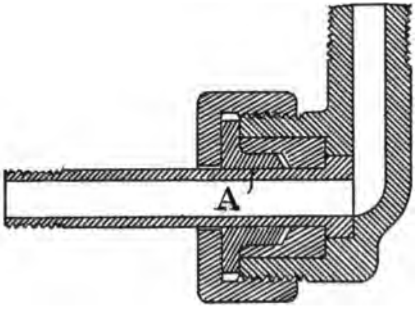

Fig. 138.

swivelling piece; *B* the pipe, which is enlarged, in this example, at *C*, although the enlarged part is sometimes the whole length of the swivelling piece; in such cases a collar is introduced on each side of the piece to prevent it sliding endways. *D* and *D* are the hat-leathers.

MacLaughlin's flexible metallic steam pipe joint is shown in sectional elevation, Fig. 135. It consists of a gun-metal bend *A*, provided with a socket at each end; these sockets are screwed on the outside, to receive the nuts *B* and *C*, and bored out to fit the nipples *D* and *E*. *F* and *G* are two woodite washers, which form the steam-tight joints. The inlet and outlet pipes are braced or soldered on to the two nipples.

Fig. 136 is a section of E. M. Dart's pipe coupling, which consists of two short pipe ends *A* and *B*; the end *A* is furnished with a small collar, and *B* with a boss, the latter being screwed on the outside to fit the nut *C*. *D* is a bush secured in the piece *A*, the collar of which bush is turned spherical, and working in the bush *E*, secured in the pipe end *B*. These two bushes are ground together, and form a steam-tight swivel joint.

Fig. 137 illustrates a swivelling joint suitable for pressures up to 800 lbs. per square inch. These joints are made of gun-metal, and consist of the elbow *A*, pipe *B*. The elbow is provided with a stuffing-box, the packing being tightened up by means of a nut *C*.

A similar joint, packed with a hat-leather, is shown in sectional elevation, Fig. 138. In this case *A* is the hat-leather.

CHAPTER XII

SUNDRY PIPE JOINTS

JOINTS FOR CONNECTING LEAD AND EARTHENWARE PIPES.

THE joint illustrated in section, Fig. 139, is for the purpose of connecting an earthenware trap with a lead soil-pipe, and was invented by Mr. D. T. Bostel. It is made of brass-work, and consists of two parts *A* and *B*, one of which, *A*, fits on to the outlet of the trap *C*, and is fixed by three studs cast on the inside, which clip into grooves made in the earthenware, and by a half-turn it is fixed. The other part, *B*, forms a cap with a female thread to fit the screwed part on *A*. To make the joint:—Slip the cap *B* on to the soil-pipe, which is then opened with a tan-pin and painted inside. The water-closet is then placed in position, and the whole screwed up, the joint being above

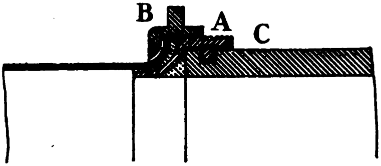

Fig. 139.

the floor. The best cement for this purpose is red lead and gold size.

Doulton's metallo-keramic joint for connecting lead and earthenware drain pipes is shown in half-section, Fig. 140. The earthenware is painted over with a metallic solution,

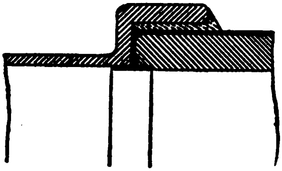

Fig. 140.

and then fixed. A thin film of metal is formed on the surface of the earthenware, and to this a branch of lead pipe is soldered, thus enabling a lead pipe to be attached by the ordinary solder joint.

Jenning's joint for connecting closet basin to metal pipe is shown in half-section, Fig. 141. The ioint is made with

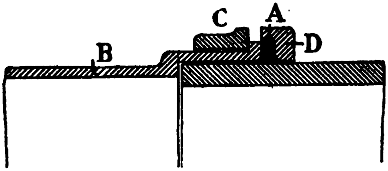

Fig. 141.

an india-rubber ring, *A*, which is tightly compressed against the flange on the lead soil-pipe *B* and the earthenware trap by means of two galvanized-iron collars, *C* and *D*, which are placed one above and the other below the ring, and drawn together by two screwed bolts.

CHAPTER XIII

CORROSION AND DELETERIOUS EFFECT OF WATER IN PIPES

To prevent corrosion, the pump-trees or rising-main, in Cornwall, were made larger in diameter and lined with staves of wood fitted with great care, otherwise the cast-iron pipes would soon be eaten away by the corrosive action of the acid contained in the water. The staves are put round the interior of the pipe, a narrow space being left between the first and the last stave; into this space are driven two wedge-shaped pieces, one from each end of the pipe.

Many other methods have been tried for preventing the liquid from injuring the pipes, and the pipes from contaminating the liquid. Mr. Charles Smith, on March 25, 1846, sealed a patent for lining cast-iron pipes with earthenware or glass tubes, also for enamelling the interior of metal pipes. He claimed to line pipes on the inside in the following manner:—On a cylindrical mandril was placed the previously prepared and closely-jointed earthenware or glass tube, to suit the length and bore of the iron pipe, which was applied thereon with the socket end downwards, and passing on to the lower projecting part of the mandril. Some metal studs were fixed in the bottom end of the mandril, applied so as to keep the iron pipe at an equal distance from the tube, to allow some adhesive cement to be poured therein, such as liquid pitch, Roman cement, or other suitable composition, to unite and hold the pipes firmly together.

Mr. Henry Cooper, in the year 1854, patented an improvement upon Mr. Charles Smith's glass-lined tubes. Cooper proceeds as follows:—A pipe of the length required is taken, and the lower end screwed into a cap or socket of iron. Then, a suitable cement having been poured into the pipe, a glass tube of any required thickness is mounted on a mandril, or rod, very slightly smaller in diameter. The mandril carrying the glass tube is inserted into the iron pipe, and guided as carefully as possible into the centre of the cement, and pressed and screwed down until the end of the mandril is protruded through the glass tube, and a similarly pointed head is screwed on the end of the mandril, so that the outside diameter of the head is the same as the outside diameter of the glass tube. The glass tube is screwed down until the semicircular head is exactly buried in a suitable recess in the cap or socket. If a sufficient quantity of cement has been poured into the iron pipe, the cement will firmly fill up the annular space between the metal pipe and the glass tube. By Mr. Smith's method the cement might not be equal in consistency throughout, hence greater pressure would be given to different surfaces of the glass lining, which was therefore more easily broken; but by Mr. Cooper's process the cement is made perfectly homogeneous. The advantage of the glass-lined pipes is self-evident.

Brighton and Venning's patent drain-pipe socket for lead-lined pipes is shown in the illustration, Fig. 142. The two pipes are lined with lead; it will be noticed that the whole of the socket as well as round the outside of the spigot are lined, the spigot end being rounded to suit the bottom of the socket. A lead or brass caulking ring is inserted into the socket, which is well caulked down. One great advantage of lining the pipes in this way is that it is impossible for the lead to collapse, as the pressure cannot possibly get between the cast-iron and the lead. These pipes are recommended for use in chemical manufactories, because they are safest and most durable for conveying strong acids. They are manufactured by the "Sanitary Lead Lining and Pipe Bending Company, Limited."

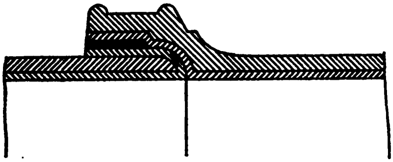

Fig. 142.

A good plan to prevent the corrosion of cast-iron pipes, consists in heating the pipes by steam, then coating them with molten pitch, both inside and outside; but the best method is to use Dr. Angus Smith's process, which is as follows:—The pipes to be thoroughly cleaned from mould, sand, and rust, heated to about 700° Fahr., then dipped vertically into a mixture of coal-tar, pitch, linseed-oil (5 or 6 per cent.), and rosin heated to about

300° Fahr., and allowed to remain until the iron acquires the temperature of 300° Fahr., then gradually withdrawn and allowed to cool in a vertical position. Perfect cohesion must take place between the casting, and the pipe must be free from blisters of any kind.

The original recipe consisted of:—

300 gallons of coal-tar,
30 lbs. fresh slaked lime,
6 lbs. of tallow,
3 lbs. lampblack,
1½ lbs. rosin,

well mixed, boiled 20 minutes, and put on hot.

The usual practice is:—

3½ barrels of coal-tar,
½ barrel coal-oil,
½ barrel pitch,

with six tons of gas coke for heating the pipes. In a wrought-iron tank long enough for a 9-feet pipe put sufficient coal-tar to half cover the pipe, then powder the pitch and sprinkle it on the tar, and the coal-oil poured on the pitch. The pipes must be heated to 180° to 200° Fahr., and put into the liquid separately and turned over and over for two or three minutes, then placed at an angle to drain, with the lower ends clear of the liquid. This quantity is enough for 1000 pieces, bends, branches, and straight pipes, or about three-quarter barrel of coal-tar for 100 lengths 9 feet long of 4-inch pipes.

Some soft water contains a great deal of oxygen, which rapidly decomposes iron, forming rust, deposited in nodules or carbuncles. These retard the flow, not so much by the reduction of diameter as by the alteration of the character of the surface.

The wear and tear by rust in uncoated cast-iron pipes exposed to the action of clean fresh water, on both sides, is not more than one-eighth of an inch in three generations.

A great advantage with the welded wrought-iron or steel pipes is their smooth and glassy surface, when properly coated. This increases the discharge of water through them, greatly reducing the friction as compared with cast-iron pipes; but this advantage cannot be claimed for riveted pipes, the projecting rivet-heads inside the pipe obstructing the flow of water, however carefully the pipes are coated.

As showing the necessity for providing against corrosion and sediment, a few examples may be cited. The author has seen a cast-iron pipe, originally of 4-inch internal diameter, reduced to a bore of 1-inch diameter by sediment; and it is stated, in reference to the subject, in Spon's *Dictionary of Engineering*, that Darcey's experiments showed that the effect of corrosion was to double the friction of the water.

In November 1899, Mr. William Ingham, Borough Water Engineer at Torquay, read before the Institute of Mechanical Engineers a valuable paper on "The Incrustation of Iron Pipes at the Torquay Waterworks." In this paper he states that, "The old main laid in 1858 is 14 miles in length, and was first scraped in 1866. It is 10 inches in diameter as far as Newton Abbot, and 9 inches forward to the foot of Chapel Hill, where it is reduced again to 8 inches between that point and the service reservoir. This main was not coated with any protective material, and within twelve months of being laid began to show signs of corrosion. Dr. Angus Smith's coating was unknown at the time the pipes were laid, and no one thought that the pure water from the Dartmoor Hills would cause such a quick and deleterious action on the pipes. It was, therefore, with considerable surprise that at the end of eight years the delivering power of the mains should be reduced to 51 per cent. of their full discharging capacity."

Another instance of the utility of a scraper is given in a Brisbane newspaper. The main pipe supplying water to the city of Brisbane was 8 inches diameter from the Errooggera storage reservoir for 5 miles, and 9 inches diameter for 2½ miles to the reservoir in the city. Shortly after completion, it was found that, in consequence of the high temperature of about 70° Fahr., and the small quantity of mineral salt, the interior of the pipe became covered with moss, especially the first half mile, and thus, with the corrosion of the metal along the whole length, not only greatly diminished the quantity of water conveyed, but also deteriorated the quality, as portions of the incrustation became detached, floated to the consumers, and even choked the supply pipes. The effect of the scraper was to increase the delivery of the main from 315,000 gallons to 360,000 gallons per day, while the quality of the water was so greatly improved that it was used for manufacturing purposes, for which previously it was unfit.

Mr. Ingham in his paper says:—"The percentage of iron in the rust is 49·03 per cent., leaving 50·97 per cent. for matter that has been deposited. This latter amount is composed of lime, organic matter, silica, carbonic acid, etc., so it is easy to trace where the different constituents were obtained for building up the nodules. A portion of the carbon, sulphur, and silicon is no doubt obtained from the cast-iron of the pipe, whilst the other portion is extracted from the solid matters carried in the water. The nodules of rust are made up of a series of layers, and these appear to increase in hardness the further they are from the centre. The centre portion of the nodule is generally made up of soft material, and when dry goes to a fine powder. The fact of there being a series of layers suggests that they are built up periodically like the rings in the harder kinds of timber. This may be due to the variations of heat, magnetism, greater acidity of water at one time than another, or some organic impurities in the water. The oxygen extracted from the water must, we know, pass through the outer layers before it reaches the iron of the pipe, and the outer layers are always less oxidized than the inner. Whenever a nodule is cut off the pipe immediately after the water has been drawn off, this top layer will be found of a dark colour, whilst the inside will be the well-known brownish-red colour of iron rust. As soon, however, as the nodule has been taken away from the water and begins to dry, this dark layer changes by oxidation into the brownish-red colour of the interior."

Mr. G. F. Deacon is of the opinion that the acidity of certain water, rather than any gases they contain, affected the pipes. He says:—"It might be true that an alkali had a slightly solvent action on the asphalt coating, but it remained a fact that corrosion was much greater in acid than in alkali waters. It was not the mere softness of certain waters that caused its rapid action upon iron; but softness in mountain waters was often associated with acidity. If the surface of the protective composition of asphalt was carefully examined after a nodule of oxygen had been removed, a tiny puncture would generally be found. It is through this hole that the growth of the nodule, for the most part at least, takes place, the oxide passing through it and spreading out in concentric layers. Beneath the nodule thus formed the iron perishes, and a spongy mass of conical shape results; the surrounding asphalt remains sound for a long time, the nodule above it and the spongy iron below being joined by the puncture. In process of time, however, the asphalt was absorbed by the nodule, and gradually disappeared."

SCRAPING MACHINES.

The idea of utilizing the pressure in the main to drive scraping machines or scrapers originated with, and the apparatus was invented by, the late Mr. J. G. Appold, and this was constructed and tried under directions of Mr. William Froude. This scraping machine is illustrated in elevation, Fig. 143. It was found that by scraping in interior of the pipe the discharge was increased 56 per cent. The scraping required to be repeated at intervals. After each scraping the discharge diminished rather rapidly by 10 per cent., and afterwards more slowly, the diminution in one year being about 25 per cent.

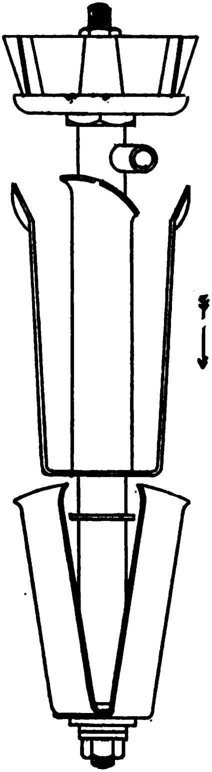

Fig. 143.

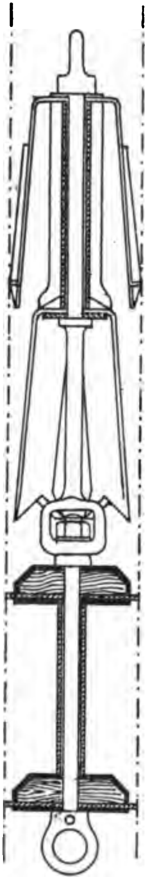

Fig. 144.

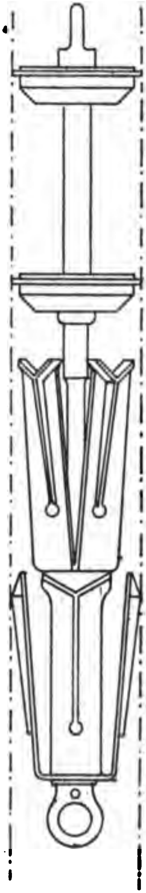

Fig. 145.

In the year 1873, Mr. Thomas Kennedy, the managing director of the Glenfield Company, Kilmarnock, devised a modification of the Appold scraping machine, and this has been in general use up to the present time. Experience has proved that the type of machine most suitable for mains ranging in diameters from 6 inches to 18 inches, is the one illustrated in elevation, Fig. 144, and sectional elevation, Fig. 145. It consists of two distinct portions connected by a swivel, the front carrying the steel scrapers, and the rear the wrought-iron or steel propelling pistons. Leather discs, intersected by radial cuts and stiffened at the back by lead plates, are placed behind each piston. The springs with the scraping edges are arranged in two sets of four each, the set behind breaking joint with that in front.

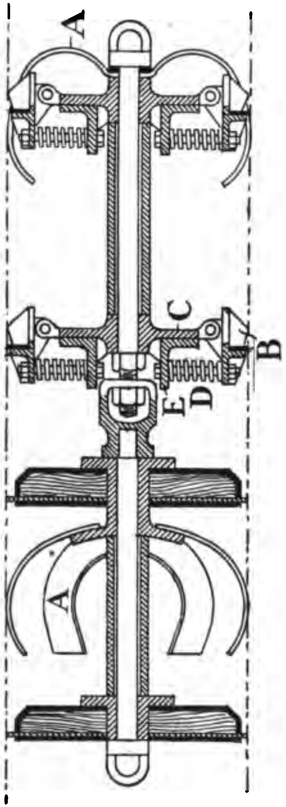

Fig. 146.

For mains of a large diameter the type illustrated in sectional elevation, Fig. 146, is to be preferred. The weight of the machine, in this example, is carried by the curved steel springs *A*, one set at each end of the

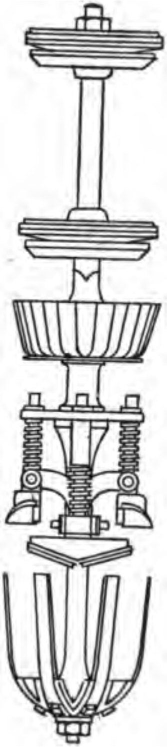

Fig. 147.

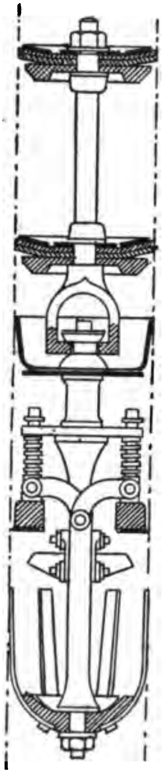

Fig. 148.

machine. The arrangement and construction of the pistons, leather discs, and swivel joint between the two parts, are similar to the machine for small mains. The scraping-knives are fixed to rocking brackets, *B*, pivoted to discs, *C*, attached to the centre rod, and are forced

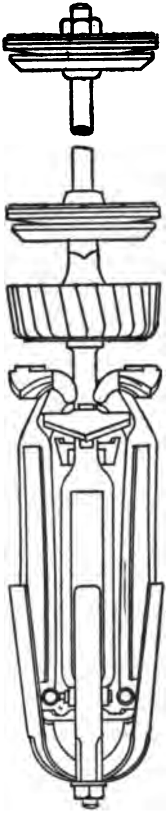

Fig. 149.

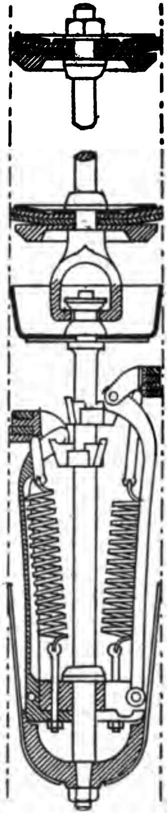

Fig. 150.

against the interior surface of the pipes by spiral springs, *D*, which are fixed at one end of the bracket, *E*, carried by the discs, *C*. There are for the 36-inch machine, six steel carrying-springs and six scraping-knives.

The Froude 8-inch scraping machine is illustrated in elevation, Fig. 147; longitudinal section, Fig. 148. It, like the Kennedy machine, consists of two parts, one the propelling, the other the scraping. The scraping-knives are secured to the centre spindle by four rocking arms, and held up to their work by spiral springs. The scraping end of the machine is carried by six steel springs.

The Froude 10-inch scraping machine is illustrated in elevation, Fig. 149; longitudinal section, Fig. 150; elevation showing front guide-arms, Fig. 151; and transverse section in front of scraping-knives, Fig. 152. This size of scraper is 3 feet 8 inches in length. The pistons are made of brass, and are about 1 inch less in diameter than the pipe. Immediately behind these pistons are leather discs strengthened by segmental iron plates; they are made rather larger than the diameter of the pipe, and the pressure of the water acting on them propels the machine forward. The rear part of the machine is connected to the front by the swivel joint, which has a considerable amount of play so as to pass round curves easily. Just in front of the joint there is a cylindrical

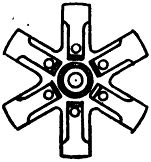

Fig. 151.

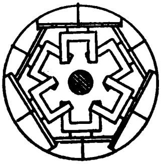

Fig. 152.

guard formed of flexible steel segments, which protects the piston leathers. The steel knives are four in number, and are kept in position by steel springs. From the nose of the scraper four pieces of steel project backwards, which serve to keep the scraper concentric with the pipe. The knives press outwards against the inside of the pipe with a force of about 48 lbs., and having a backward as well as a radial motion, they give way on meeting a projection which causes a pressure on the point of the knife of 60 lbs. The knives are rather more than one-fourth of the circumference in length, and are in pairs diametrically opposite to one another, one pair being about 4½ inches in advance of the other; they are V-shaped, and the scraper moves bodily round if they meet with a ferrule or anything of that kind. The two pistons already referred to are placed at such a distance apart that they will cover the largest hole of any branch pipe from the main, otherwise the water would rush past the pistons and cause the scraper to stop. The force required to drive a 10-inch machine at Torquay is from 350 to 400 lbs., or about 5 lbs. per square inch; but for the smaller machines the pressure required would be much more, because the area of a small pipe compared with the circumference is much less than in the larger sizes. For instance, comparing a 6-inch with a 10-inch, the area of the 6-inch is 28·3 inches and the circumference is 18·86, while that of a 10-inch is 78·6 and 31·4 respectively. The ratio of the area to the circumference in the 6-inch pipe is nearly 1½ to 1, and in the 10-inch 2½ to 1; therefore, if 400 lbs. would move the 10-inch scraper, 667 lbs. would put the 6-inch in motion if the rust was similar in both cases.

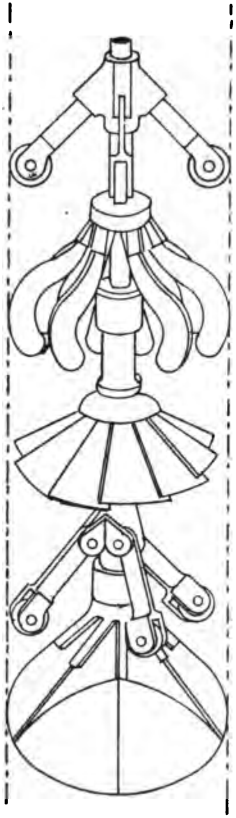

Fig. 153.

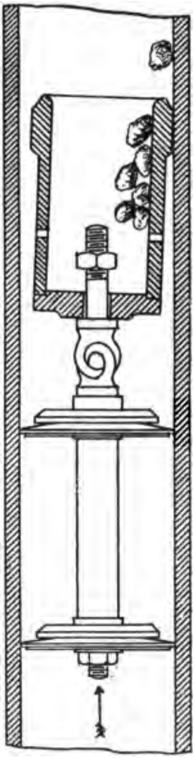

Fig. 154.

The scraping machines are placed in the main by removing the cover from a box. The cover is then replaced, water pressure admitted behind the pistons, and the apparatus driven through the main by the pressure of the water. The boxes are placed at intervals on the main for introducing or withdrawing the machines.

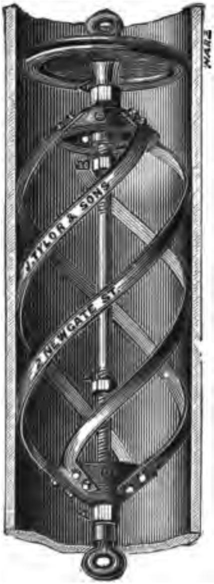

Fig. 155.

At Lancaster, after twice scraping, the discharge was increased 56½ per cent.; at Oswestry 54½ per cent.

The increased discharge is of course due to the diminution of the friction of the pipe by removing the roughness due to oxidation.

An American rotary scraping machine, illustrated in perspective, Fig. 153, has been used with very good results for cleaning oil-mains. These have been used for years.

Where scraping is necessary, it is not advisable to have the radii of curves in the pipe-line under 30 feet, although in well-proportioned scrapers fifteen times the diameter of the pipe will be sufficient.

Appold's stone remover is illustrated in part sectional elevation, Fig. 154. The illustration is so clear and the construction so simple that no description is necessary. It is worked, like the scraping machines, by the flow of the water in the pipe.

The scraper illustrated in Fig. 155 has been extensively used in the Colonies for some years, and has been found most successful. By means of the nuts *A* and *A*, and *B* and *B* on the spindle, the scraper can be made to suit different sizes of pipes; *C* and *C* are gun-metal cone-pieces, which allow the scraper to revolve on the spindle if it comes in contact with any of the fittings projecting through the pipe. It can be driven either by water-pressure or ropes attached to the eyes on each end.

The following list gives a summary of scraping water-mains by water-pressure:—

Year.	Name of Place.	Diam. of Main.	Length of Main.		Total.	Cost per yard.	Obstructions.	Gain in delivery after scraping.
		Ins.	Mls.	yds.	£	*d.*		Per cent.
1877	Oswestry	7 6	1 4	440 660	121	2·98	Large stones, lead, and defective pipes	54·4
1878	Lancaster	8	1	1,500	30	2·2	Peaty matter	56·1
1880	Durham	12	1	586	91	9·1	Lead, spade, hard spike, and wagon-spring	
1880	Bradford	18	4	1,100	634	18·6	Stones, lead, crow-bar, etc.	55·6
1881	Halifax, N.S.	12	1	573	91	9·3		
1882	Exeter	10 12	2 2	0 0	192	6·5		
1883 1885	Whitehaven	13 11	2 3	1,056 1,232	516	11·1	Mussels, stones, and lead	27·6
1885	Bristol	6	1	785	35	3·3	Stones	
1886	Denbigh	6	1	880	150	13·6	Stones, gravel, and lead	
1887	Omagh	6	2	792	53	2·9	Lead and defective castings	300·0
1887	Halifax	6	0	776	21	6·5		
1888	Ulverston	6	1	0	72	9·8		
1890	Dundee	15	2	0	256	17·4	Wood and stones	
1890	Dumfries	9 8	1 4	0 0	113	3·0	Stones	
1890	Scarborough	8	1	440	62	6·7		
1891	Newport	10	0	1,080	50	11·1	Lead	
1891	Lanark	7	6	880	75	1·57	Lead, wood, and stones	33·7
1891	Gainsborough	6	1	0	36	1·84		
1891	Newport	5	0	75	8			
1892	Rouboux, France	24	5	594	242	6·1		16 ft. head taken off pumping engine
1892	Burntisland	8	8	1,320	252	9·02	Piece of wood 2 feet 3 ins. by 5 ins. by 5½ ins., lead 4¾ lbs., and stones	43
1893	Thurso	6	3	0				7
1898	Bridge-of-Allan	6	1	0				35
1894	Stirling	8	3	1,320			Stones and lead, and pieces of broken pipe	
1894	Inverkeithing	5	2	880			Lead	
1894	Waterford	13	8	0	211	3·11	Pieces of broken pipe, rope	40
1895	Cupar, Fife	7	3	880	67	2·6	Pieces of broken pipe, rabbit	52
1895	Merthyr Tydfil	14	5	617	818	8·01	About 400 stones	30
1896	Cowdenbeath	6	3	1,405	90	3·26	Lead	23
1896	Merthyr Tydfil	12	6	770	178	3·76	Pieces of broken pipe, lead, and stones	82
1896 1897	Kendal	6 4	1 0	1,430 830	54 22	4·08 6·32	Lead, rust, and peaty matter Rust and peaty matter	

CHAPTER XIV

TESTING PIPES

PIPE-TESTING is a very important subject, and should be done very carefully and thoroughly, or a great loss of time and money is in jeopardy.

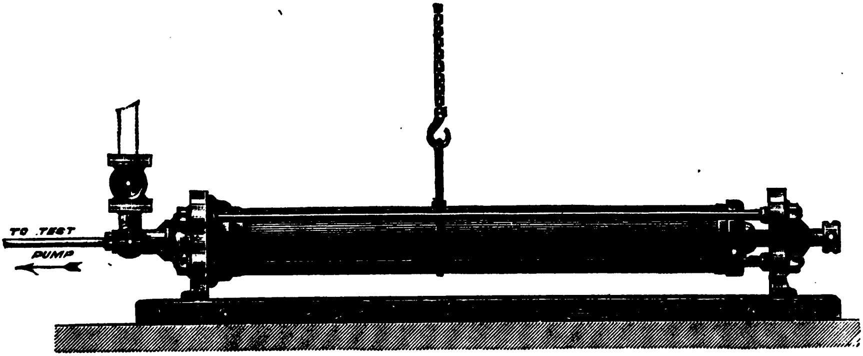

Fig. 156.

If the pipes are small the machine illustrated in Fig. 156 should be used for all classes of pipes, except earthenware, stoneware, and fire-clay pipes, which latter are tested in a special machine, which will be described further on in this chapter. For testing steam, water, or gas pipes, with flanged or socket ends, this is a very

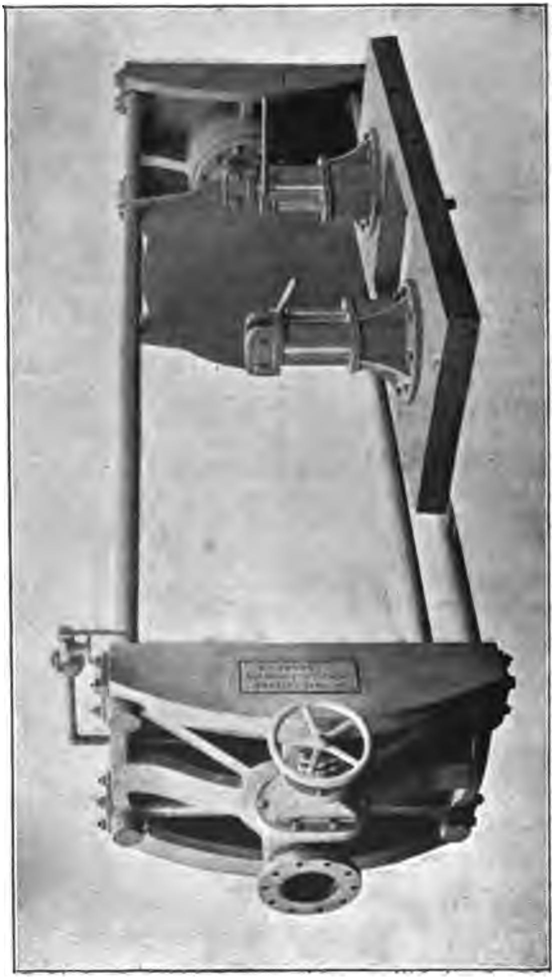

Fig. 157.

handy machine. To make the test, the pipe is placed into position between the two head stocks. The apparatus being connected to the town's main, the pipe under test is rapidly filled with water; hydraulic pressure is then applied by means of a test-pump, or in cases where large quantities are to be tested to the same pressure a water tower is used, or a weighted accumulator, arranged for varying the quantity of weights.

An hydraulic testing machine for large pipes is illustrated in Fig. 157. This machine will test pipes up to 48 inches diameter, and 13 feet long, to 200 lbs. per square inch. The hydraulic cylinder is 12 inches diameter, made of cast-steel, the ram having a run out of 16 inches, and exposed to a pressure of 1¼ ton per square inch. The fixed headstock is fitted with a sluice-valve for filling the pipe. The machines are fitted with four cast-iron rails, for carrying the pipes, and two cast-iron rams, with guides and screws for raising and lowering the rails. This machine is made by Hayward, Tyler & Co., of London.

It is very important that an air-cock should be provided to allow the air in the pipe to escape during the process of filling it with water from the main or any other source.

In the author's opinion the test pressure specified is, as a rule, put too high, and by that means straining the metal unnecessarily. If the pipe is tested for one half hour with one and one-half times its working pressure, and well tapped all over with smart blows with a light hammer (not a blow here and there with a sledge-hammer, which we have seen done on several occasions), it is quite safe, if the pipe stands the test well. If the pipe proves rather doubtful, then increase the pressure.

Particular notice should be taken of the metal round chapels, if any have been used, as those places are frequently very spongy and honeycombed.'

Bends and irregular-shaped cast-iron pipes are, as a rule, especially in America, not tested with hydraulic pressure, but we think it is just as important, if not even more so, to have them tested. In such cases flanges must be secured on the ends of the bends or pipes, and a small pipe from a test pump secured to one of the flanges, and a pet cock for relieving the air in the other flange, and the same process gone through as for straight pipes.

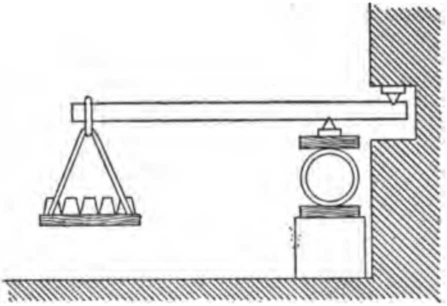

Fig. 158.

When the test pressure has been reached, the cock between the machine and the pump should be turned off; should the pressure diminish, which is easily seen by the pressure gauge, the pipe and the joints at the ends must be carefully examined, and any leakage at the ends

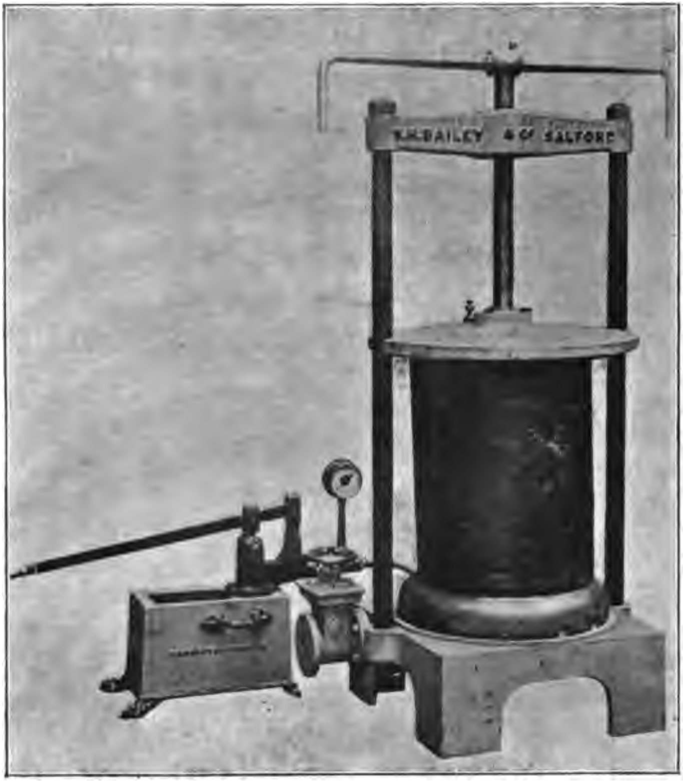

Fig. 159.

stopped at once, and the pressure again raised to the required point.

The machine, for testing earthenware and stoneware pipes, which was used by Mr. J. W. Bazalgette and Mr. William Haywood, is illustrated in Fig. 158. It consists of a beam resting on a V-centre in the wall and one on the top of the pipe. During the experiments each pipe was placed on two flat pieces of hard wood, and a piece of hard wood was laid on the top of the pipes, the weight

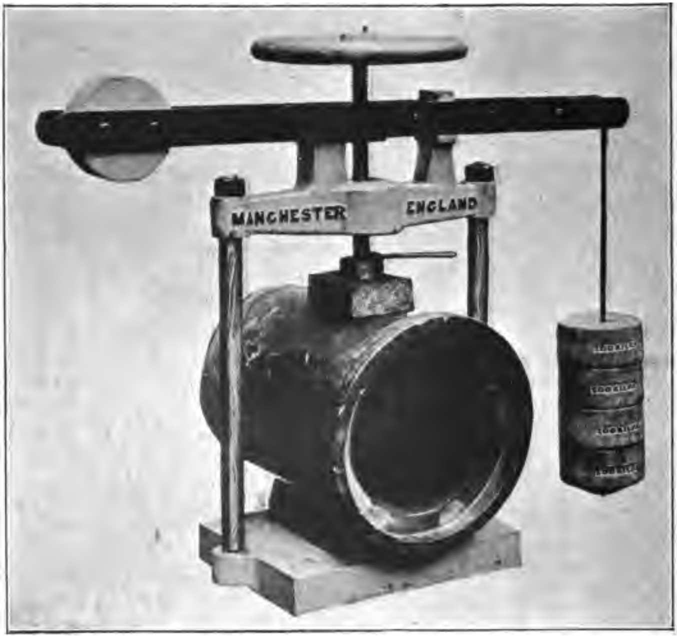

Fig. 160.

being applied by means of the lever. In some of the experiments a packing of felt was placed round the pipe.

A modern machine, for testing sanitary pipes, manufactured by Messrs. Bailey, is shown in Fig. 159; this machine is made to test pipes up to 18 inches bore and 3 feet in length by applying hydraulic pressure. The hydraulic pressure is obtained by means of the hand-pump shown on the left-hand side of the machine, and the pipe is filled from the main through the sluice-valve. The pipe is placed on the base of the machine socket downwards, the joint top and bottom are made, and the top is screwed down by the cross handle at the top and the central screw, which works in a nut provided in the cross-bar.

The machine illustrated in Fig. 160 is for testing the crushing strength of sanitary pipes. The machine is made to take pipes up to 18 inches bore, and gives a maximum crushing strain of 2,000 lbs. The pipe is placed in the machine on a hard wood block curved to suit the radius of the pipe, another smaller block on the top, and the hand-wheel and screw turned till the pipe is held secure in the machine; next weights are placed on the end of the lever till the required test pressure is obtained.

CHAPTER XV

LAYING OF PIPES

In laying sewage or drain pipes the spigot end should always be lower than the socket, and great care should be taken that the spigots are perfectly central with the socket.

The bottom of the sewage pipes should be perfectly in a line, so as not to cause any obstruction to the flow of the sewage, or lodgment for sediment.

The pipes from the pumping station to the distributing reservoir—and generally all pipes required for a town distribution—should be laid about 4 feet below the surface, and be covered with earth and sand, or some material non-conducting of heat.

Sewer pipes must be laid in a perfectly true line of fall from point to point of the sewer, and the pipes must have an uniform bearing the whole of the way. A recess should be provided in the floor of the trenches to receive the socket. In making the joints several strands of tarred gaskin should be pressed to the bottom of the socket, by means of a properly made caulking tool shown in Fig. 161, and afterwards the joint may be made with clay or cement. When clay is used a tool should be employed for forcing it into the socket; after the socket has been filled a fillet of clay should be worked round it to complete the joint. The cement is better in cases where there is a great amount of water in the soil or where there is quicksand. The cement should be mixed with sand in the proportion of from 1 to 1, or 1 to 2. The joint of sewer pipes carried under houses should be made of asphalt.

Wherever the size of the pipe will admit of it, a man or boy should be employed inside the pipe, as they are being laid, to make good, with some of the best jointing material, the inside of the joint.

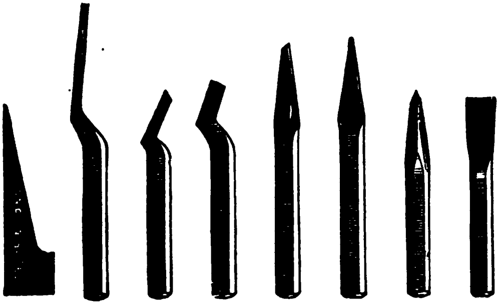

Fig. 161.

Great care should of course be taken, so that the spigot is perfectly central with the socket.

Making lead joints must be done very carefully. The spun yarn must be wound round the spigot and forced to the bottom of the socket by the tools illustrated in Fig. 161, and driven in so as to leave a space of about 2½ inches in front of the yarn. An iron ring is next clasped round the pipe, bevelled away at the lead space, and generally kept about ⅛ of an inch in front of the socket, this space being clayed round to prevent the molten lead from escaping. A better plan is to adopt Messrs. J. Tyler and Sons' elastic clip, illustrated in Figs. 162 and 163.

Next the lead is run in, care being taken to have the exact quantity of molten lead in the pot, and that there shall be no check in the process of running, which might cause a flaw in the joint and liability to crack in the caulking.

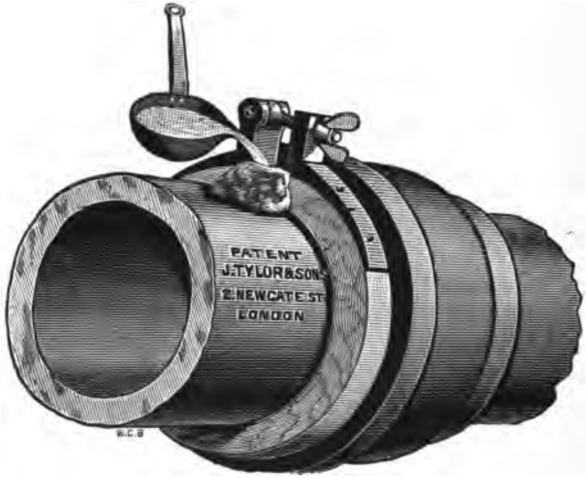

Fig. 162.

When the lead has become cool, the lead outside the socket must be removed with a flat chisel and caulked with three properly proportioned tools, illustrated in Fig.

161; this process must be carried continuously round the joint with each tool. Sometimes the yarn is dispensed with, and a lead rod substituted, with the advantage that the pipe socket can be made shallower.

If double sockets are used the caulking must be proceeded with at the same time on each side, and the men should keep time with one another, or one man might, at every stroke, undo what the other man has just done with the previous blow.

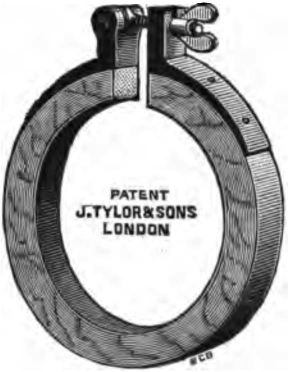

Fig. 163.

A new fusible alloy has just been brought out by the Phelps' Metal Company, Laurence Pountney Lane, London, under the name of Phelps' metal, which bids fair to outdo lead for socket joints. This metal melts at about 300° Fahr.; lead melting at 606°. It possesses extraordinary adhesive power to almost anything except glass. It is not affected by acid; it does not rust; it is not affected by atmospheric influences; it can be cast on or in almost any material, including gelatine and paper; it can be re-melted and cast as often as desired, and is one-third the weight of lead. The A1 quality costs £20 per ton, and as the market price of lead now is about £16 per ton, the cost of Phelps' metal is cheaper, as one ton of the latter metal has three times the bulk of lead. Another great advantage of this metal is that it requires no caulking.

When rust cement is preferred for making the joint tight in socket pipes care must be taken that the iron borings are quite free from grease, therefore it is best to make them red-hot before using them; this will remove all grease. There must not be too much sal-ammoniac or the socket might burst. The following are two good mixtures:—

Powdered sal-ammoniac	1 part
Flour of sulphur	2 parts
Iron borings	100 „

Or for slow-setting rust cement—

Powdered sal-ammoniac	2 parts
Flour of sulphur	1 part
Iron borings	200 parts

A good cement for hot-water pipes is made by

Litharge	1 part
Chalk	2 parts
Silver sand	3 „

Mixed with boiled linseed oil to the consistency of stiff putty. This cement has to be caulked in with yarn.

In laying pipes which will eventually require scraping, the making of the pipe-joints should be carefully watched to see that no lead finds its way into the pipe, to obstruct the passage for the scraping machine.

Water pipes should never be laid in the ground to a depth less than 1 foot 6 inches in Great Britain, but in cold countries such as Russia, Sweden, Norway, etc., not less than 2 feet 6 inches.

Petroleum pipe lines.—The Olean, Callarangas Company, N.Y., pipe line, which has an elevation of about 1500 feet above sea level, consists of two 6-inch pipes, tested to bear a pressure of 2000 lbs. per square inch. These pipes are screwed together at the joints with couplings, as the ordinary gas pipes, already explained on page 62. In order that the pipe and the oil shall not be affected by every change in temperature and to practically overcome the extreme of heat in summer and cold in winter, the pipes are buried into the surface of the ground to an average depth of about two feet. The pipes are laid in as nearly straight line as possible, and follow the contour of the country, up hill and down. At one point in Alleghany county the line overcomes an elevation of nearly 1300 feet within a distance of four miles.

Mr. F. S. Pecke, a civil engineer of Watertown, N.Y., had occasion to lay nearly 1000 feet suction-pipe at Rouses point. The water was needed for manufacturing purposes, and as it was found that the water near the shore was more or less oily and impure, it was necessary to have the strainer of the pipe a considerable distance out into the lake. He purchased for the purpose spirally-welded tubes or pipes 8 inches diameter, and used for couplings cast-iron flanges, weighing with bolts and gaskets about 65 lbs. to the pair. Plugging the end of the first length, he pushed it on the surface of Lake Champlain, and connected the second length, pushing this out in turn, until the whole line was completed. This process he continued till he had a line of 8-inch pressure pipes nearly 1000 feet long, floating with a displacement of only 3½ inches of its diameter. When the requisite length had been connected, the line was towed to position, the plug at the end removed, and the pipe sank easily in 11 feet 6 inches of water, without breaking a joint or receiving any injury. No buoys or floats were used in the operation, and no apparatus of any kind. Works of this kind usually involve the use of expensive and frequently troublesome ball-and-socket or flexible joints, such as have been previously described and illustrated on pages 40 and 82.

EXPANSION JOINTS.

All classes of pipes must, if exposed to changes of temperature, be fitted with an expansion joint of some description or another. The old-fashioned disc joint is illustrated in elevation, Fig. 164, and end view, Fig. 165. It consists of a wrought-iron or cast-iron ring, on each side of which is riveted a copper disc, at the centres of which are riveted cast- or wrought-iron flanges, the rivets being countersunk on the faces of the flanges. This joint does very well if properly made, large in diameter, and for low-pressure steam. A drain-cock should be provided on the bottom side in the centre of the ring, to allow condensed steam to escape.

The copper bellows expansion joint is illustrated in elevation, Fig. 166, and front view, Fig. 167. This is an admirable joint for moderate pressures. It is worked out of copper, having brass flanges brazed on. When all the pipes are cold, the space for the expansion box should be

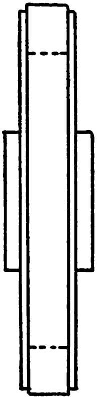

Fig. 164.

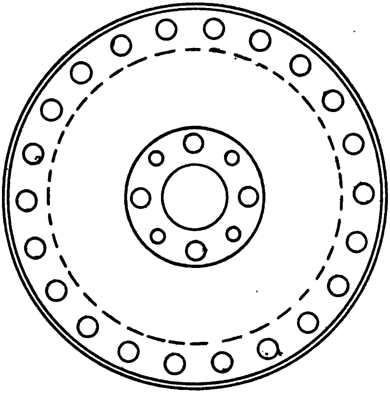

Fig. 165.

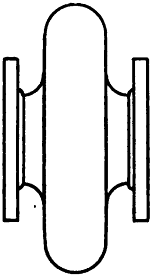

Fig. 166.

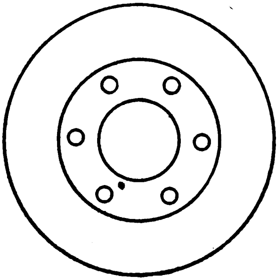

Fig. 167.

about one-quarter of an inch greater than the length of the box over the flanges.

The ordinary cast-iron expansion joint consists of a short casting or pipe arranged to slide inside another, which latter is provided with stuffing-box to prevent the steam escaping between the two, as illustrated in Fig. 168. This arrangement is usually made of cast-iron, and was first designed when pressures were very low. While the pressures remained low it answered the purpose fairly well, as the pipes could readily be anchored or fastened at the ends, and the range of temperature not being great, the expansion would be taken care of by this apparatus. As the pressure increased, however, the end strains on the pipes became a serious moment, the tendency being to blow the joint apart; in consequence, stops had to be provided to prevent this taking place, otherwise these joints would have been a source of danger.

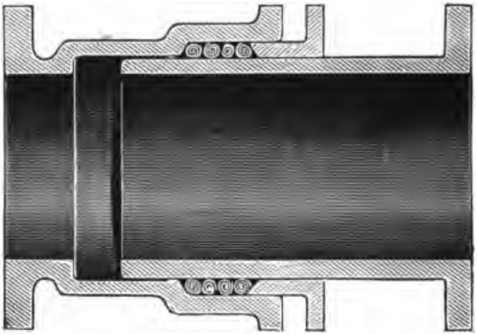

Fig. 168.

Various arrangements were made to admit of these higher pressures without danger. Of these one of the best is illustrated in section, Fig. 169. In this joint the shell and sliding part are made of forged steel, while stops are provided that effectually prevent the pipes being blown apart. This arrangement answers for comparatively short straight pipes, where an end pressure does no harm, but with this, as with other joints, under the heavy pressures at present in use, if the pipe has bends or turns which allow of it being forced endwise, the sliding pipe of the joint is usually forced hard against the stops, and it remains in that position almost as if it were a fixture, the apparatus becoming an expansion joint in name only. The expansion and contraction which takes place, due to the temperature of the high pressure and, in many cases, highly superheated steam, forcing the ends of the pipe apart as the pipes heat and drawing them together as the pipes cool, thus constantly swaying them backward and

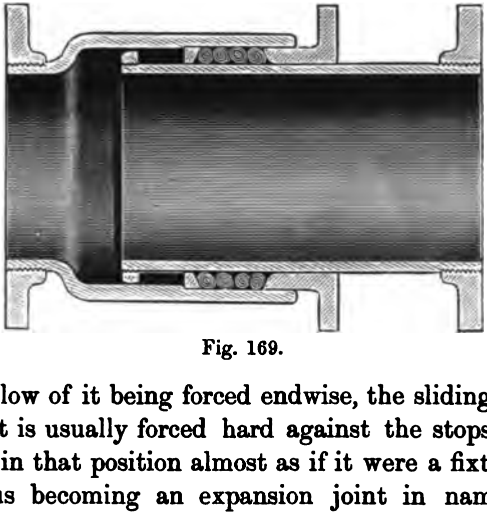

Fig. 169.

forward, excessively straining the pipe and its connections, and causing the joints to leak and blow out, bolts to give way, flanges to break, valves and fittings to crack, and giving endless trouble, worry, and expense, in attempting to keep the pipes in order. In many cases duplicate lines of piping are installed to provide against these accidents, which engineers are beginning to look upon as inevitable.

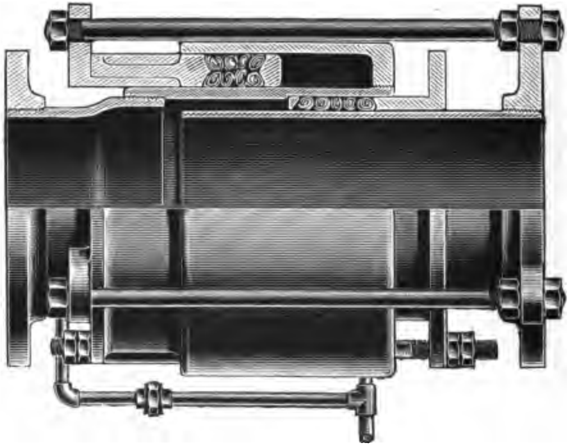

Fig. 170.

The balanced expansion joint, manufactured by Messrs. Brown and Company, of Manchester, is illustrated in half elevation and half-sectional elevation, Fig. 170. An annular chamber, provided with a special packing-box and piston, surrounds the shell in which the sliding pipe works, the area of this annular piston being equal to that of the sliding pipe, to which it is attached by means of the long bolts shown. Connections are made between the pipe and annular chamber, so that the pressure is the same in both, and as the pressure tends to force the sliding pipe in one direction and the annular piston in the opposite one, these forces balance each other, and therefore the pipe is free to slide in or out of the expansion-joint without regard to the pressure in same. They are made of steel forgings, with the exception of the glands, which are castings.

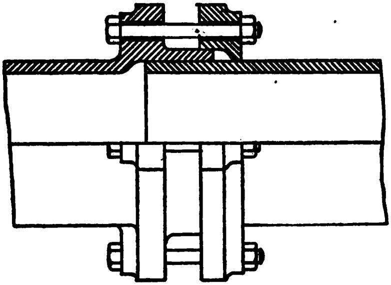

Fig. 171.

A hot-water pipe expansion-box is shown in half-elevation and half-sectional elevation, Fig. 171. It will be seen that one end of the pipe acts as a spigot, the other as a kind of stuffing-box. The gland is secured by four bolts, in the present case; the packing being placed in the gland.

Jones' improved expansion joint for hot-water pipes, for low pressures, consists of two loose flanges, as will be seen from Fig. 172, and one iron ring, and is made by compressing, with two bolts and nuts, two india-rubber rings, between the ends of the ring and the shoulders inside the flanges, thus binding the rubber rings firmly round the pipe about one inch from the end of each. This joint may safely be used with 100 feet head of cold water, but they are not suitable for more than 25 to 30 feet of hot water.

These joints are moderately cheap, quickly made, not liable to fracture from expansion or contraction, they may be fixed by inexperienced persons, and alterations or additions can be made in one-fourth the time that would be required with most other systems of jointing, and in case the water in the pipe should be frozen, the joint is forced off by the expansion, and frequently without damage to pipes, joints, or connections.

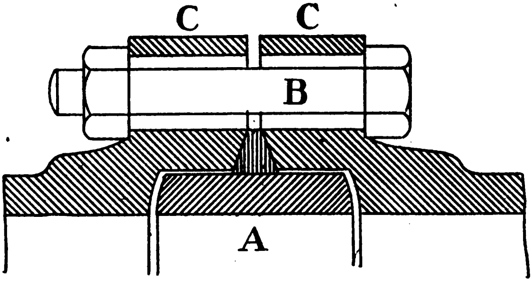

Fig. 172.

Jones' patent "Grip-fast" pipe joint is shown in illustration, Fig. 173. It is a loose coupling for connecting the plain ends of cast-iron, wrought-iron, or any other metal pipe for hot water, cold water, exhaust steam, gas, or compressed air; it is specially adapted for lofty buildings where the head or pressure of water is too great for the usual expansion joint. This joint will stand 100 feet head of hot water, or 200 feet head of cold water pressure. It consists of the two plain ends of pipes fitted with two flanges, *A* and *A*, inside of which are provided wedge-shaped split-rings, *B* and *B*. *C* is a middle ring on each side of which is furnished india-rubber rings, *D* and *D*. It will be noticed that the wedge-shaped split-

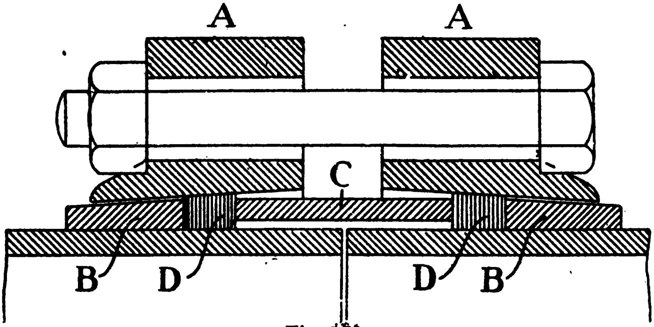

Fig. 173.

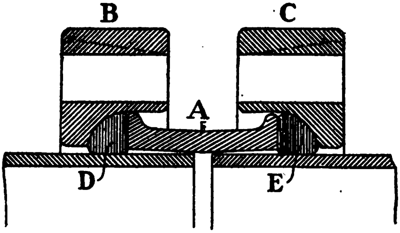

Fig. 174.

rings will grip the flanges and pipes tighter the harder the flange bolts are screwed up. The makers are Messrs. Jones and Attwood, of Stourbridge.

The expansion joint adopted by Mr. Deacon for water mains has a French origin. It is illustrated in section, Fig. 174; it consists of a wrought-iron ring, *A*, two flanges, *B* and *C*, and two india-rubber rings, *D* and *E*; the flanges are drawn towards one another by the bolts, which squeeze the india-rubber rings tight to the joint. This is very well if the pipes are bedded in the ground, and the joint bedded in the soil, so that it cannot shift; but if the pipes are above ground and at an angle, the joint will soon slide away from the ends of the pipe and leave the space open for the liquid to flow out of the pipe. In such cases one flange must be fixed to the one pipe and a permanent joint made on that side, so that there is only one india-rubber ring exposed to wear, whereas in Mr. Deacon's joint both india-rubber rings will wear. The latter is the joint which has been adopted for the Coolgardie Gold-field water supply mains, in which one of these joints are placed at every 100 feet.

CHAPTER XVI

DRILLING AND RIVETING MACHINES FOR PIPES

DRILLING MACHINES.

THE drilling of pipes, when there is no pressure in them, can be done either by a ratchet-brace, as illustrated in Fig. 175, or a small drilling machine worked by a small hand-wheel and gearing; but a more complicated apparatus is necessary when the pipes have to be drilled and tapped under pressure.

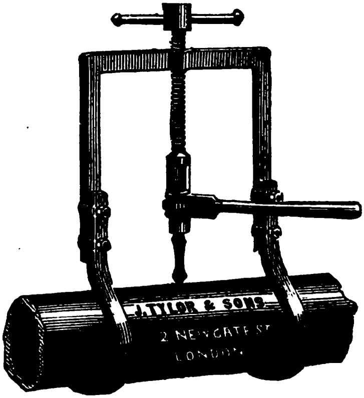

Fig. 175.

One of these machines, patented by Mr. O. Browne, and manufactured by Messrs. J. Tylor & Sons, of London, is illustrated in Figs. 176, 177, 178, and 179. By the use of these ferrules house services can be connected to mains without shutting off the water, and without the use of any cumbersome apparatus. The method of using this

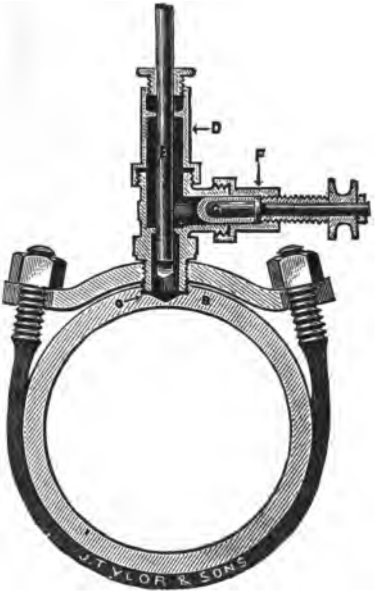

Fig. 176.

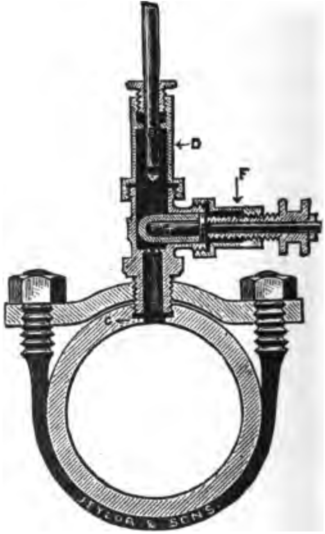

Fig. 177.

apparatus is as follows:—By means of an ordinary ratchet-brace and a drill, a recess is made in the main as at *B*. The lip is then placed in position, the ferrule screwed through it—a lead washer having been placed in the recess,—and the two nuts are tightened until a joint is made between the ferrule and the main. The cone and spindle of the ferrule are now removed, and the guide *D*, through which passes the drill *E*, is screwed on in their place. The cap and lining on the outlet of the ferrule are replaced by the chamber *F* and plug *G*, as shown in Fig.

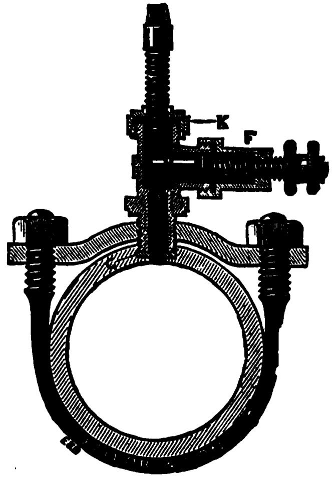

Fig. 178.

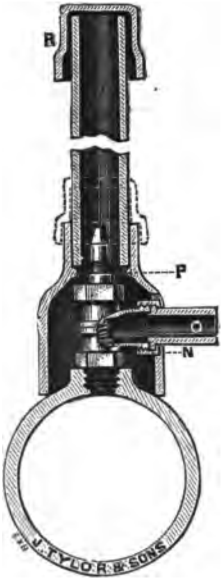

Fig. 179.

176. The drill *E*—which is of the usual shape, and much smaller than the one previously used—is forced down, and the hole drilled right through the main. A small pet cock may be fixed in chamber *D* to allow the iron borings to escape. The drill is now withdrawn, and the plug *G*

screwed home, making a joint in the ferrule, as illustrated in Fig. 177. The escape of water being thus prevented, the guide *D* may be removed, and the cone and spindle replaced, as shown in Fig. 178. The plug *G* is then withdrawn within the chamber *F*, and the spindle having been screwed down on the seat *M*, the chamber *F* with its plug *G* can be removed, and the cap and lining *NO* replaced, and the laying of the service proceeded with A cast-iron

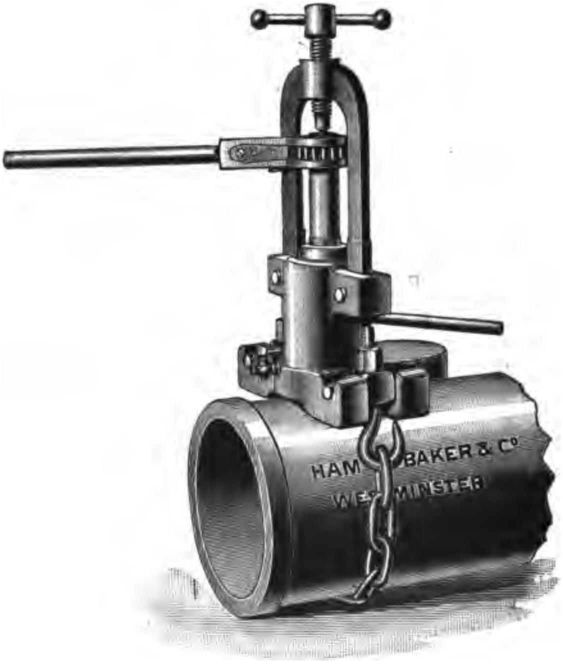

Fig. 180.

bell-cover *P* is sometimes provided to protect the ferrule from being injured.

A drilling machine for drilling and tapping large mains under pressure, manufactured by Messrs. Ham, Baker & Co., London, S.W., is illustrated in Fig. 180. The drill, taps, and ferrules are held firmly in chucks of special construction, which keep them in exact position, ensuring the ferrule tap being properly fixed in main. This apparatus will not only put in the ferrule, but it will also take it out under pressure and replace it with another; or when the service is being dispensed with, a plug can be inserted in the main, which cannot be done by any other machine that has come under the author's notice.

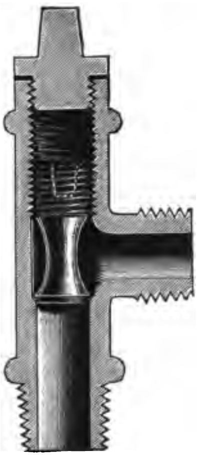

Fig. 181.

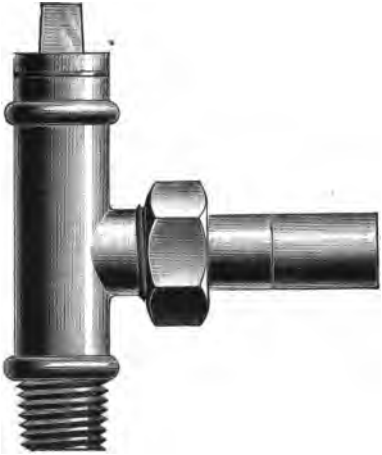

Fig. 182.

The ferrule for use with this apparatus for tapping water-mains under pressure is illustrated in Fig. 181 and Fig. 182.

The method to be adopted in using this apparatus is as follows:—Select a suitable saddle-piece, fix the apparatus over the main, tighten up by means of the screws, try disc handle to see that it works easy, place drill in chuck and pass through barrel of apparatus, attach ratchet-brace and work down screw until tight; then, seeing that valve is open, work away with the brace, following up feed by screw, until the hole is through the main, withdraw the

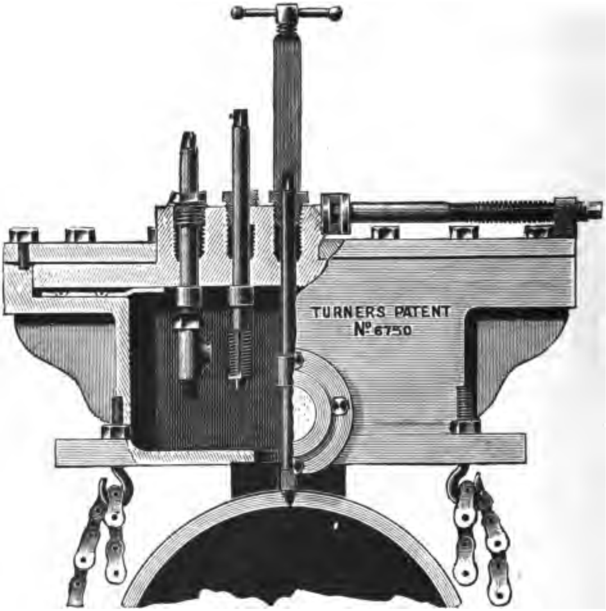

Fig. 183.

chuck, close disc valve to test that it is closed, try with pet cock. Take out chuck and drill and insert screw tap, work ratchet as before described; this will cut the thread, when ferrule may be inserted in a similar manner. When ferrule tap has been screwed into the main, do not withdraw chuck, but slack off chain and lift apparatus bodily over the ferrule and chuck, the detach chuck and screw ferrule tap further into the main if required.

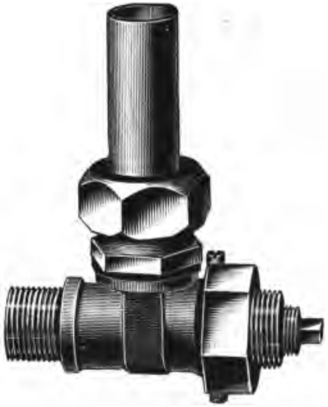

Fig. 184.

Turner's Patent Tapping Apparatus.—This patent apparatus is illustrated in half-sectional elevation, Fig. 183. The illustration is so clear that it requires hardly any explanation except how it is manipulated. First see that the drill and tap are of the required size in the machine; then screw a ferrule on the spindle furthest to the left; then place the apparatus on the main, using the rubber saddle-ring to make the joint. Fasten the box firmly with the nuts attached to the hooks. Screw up the movable slide until the line on it, where the drill spindle is, is parallel with the line on the top of the box, adjust the ratchet brace, and commence drilling. As the drill-

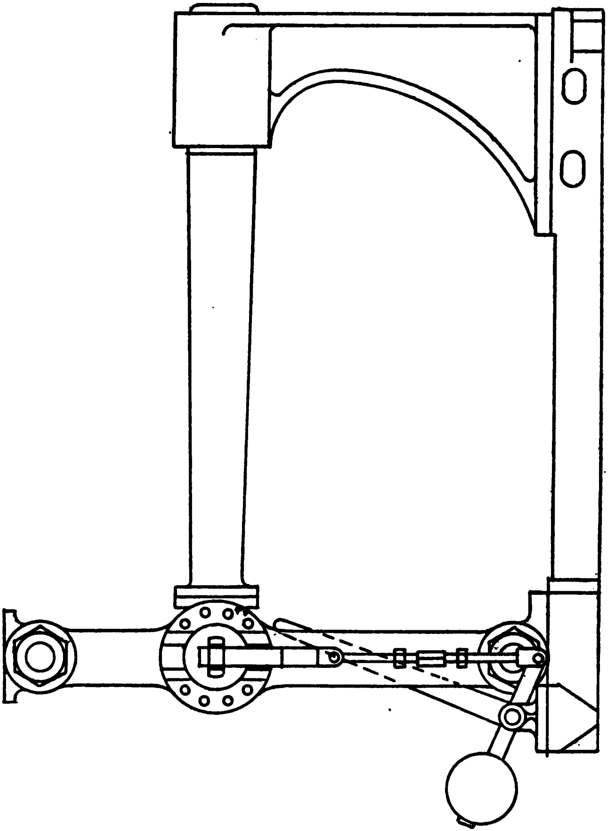

Fig. 185.

point is working through the main take off the pressure, and there will be no danger of breaking the drill as the water forces its way into the box. After the hole is drilled, draw back the spindle as far as possible, then

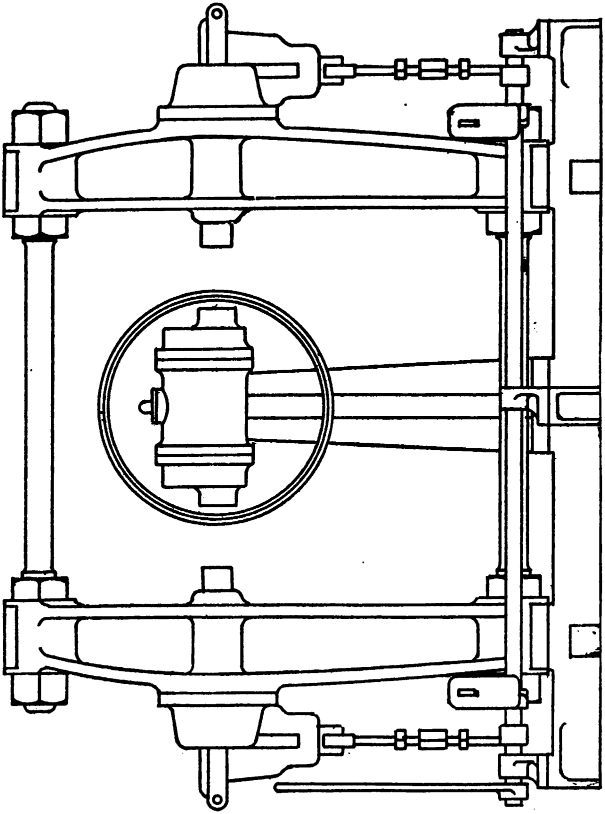

Fig. 186.

screw the slide until the tap spindle is over the hole and proceed to tap, using the provided wrench. After the hole is tapped, draw back the spindle the same as the drill spindle, then screw the slide until the ferrule-spindle is over the hole; put in the ferrule, and when this is screwed right down unscrew the spindle from the ferrule, and the operation is complete, and the apparatus can be removed. Fig. 184 is an enlarged view of the ferrule.

RIVETING CIRCUMFERENTIAL SEAMS OF PIPES.

In long pipes there has always been a trouble with the circumferential seams; they have always to be riveted by hand, or a tremendously heavy hydraulic riveting machine has been employed. Messrs. Piggott have overcome this difficulty by their patent "Duplex Riveter," which is illustrated in side elevation, Fig. 185; and front view, Fig. 186. It will be seen from this that any length of pipe can be riveted, and two rivets are closed opposite each other at the same time. The pipe lies on a trolley (not shown in the illustration), which is capable of adjustment in every direction. In this machine, besides the advantage of riveting a long steel pipe without any shock—owing to the perfect adjustment of the carriage, and the two rivets being compressed exactly opposite to each other—the cost of riveting is only about two-thirds the cost of ordinary machine riveting.

PAPER PIPES.

Gas pipes from paper were made from strips of Manilla paper equal in width to the length of the pipe to be made, which was passed through a vessel with melted asphalt, and then wrapped firmly and uniformly around an iron core until the required thickness was attained. The pipe was then subjected to powerful pressure, after which the outside was strewn over with sand, and the whole cooled in water. The core was then removed and the inside of the pipe coated with a waterproof composition.

LAYING MAINS UNDER WATER.

A very simple method was adopted in laying a water main under the river St. Joseph, in the year 1888. The main was 10″ diameter, 800 feet long. A double line of posts were set up, and braced by string pieces and cross pieces, which received the pipe. After all the pipes in the section to be laid had been caulked, wooden rollers were set above them, ropes passed under the pipe at each socket, and the ends brought up and fastened to the rollers above, upon which all the slack was wound up. When everything was in readiness, two men were stationed at each roller, and turned it enough to just take up the weight of the pipes. The cross pieces, etc., were knocked off; and the pairs of men, alternately settling their levers in the holes, gradually and uniformly lowered the pipe into position on the river bottom, which had been dredged sufficiently to form a regular bed. One ball-and-socket joint was used in the length of pipe. Ten men in ten days' time built the scaffold, caulked the pipes, and removed the scaffold after laying; and eighty men in two hours lowered the entire length of pipe complete.

CHAPTER XVII

TABLES

TABLE I.—FRICTION OF AIR, STEAM, AND GAS IN LONG PIPES.

(T. Box)

Diameter of pipe in inches.	Head or difference of pressure at the two ends of pipe one yard long in	
	Inches of water.	Pounds per square inch.
	Head for one cubic foot per minute.	
¼	1·477	0·05317
⅜	0·1945	0·00700
½	0·0185	0·000666
¾	0·006077	0·0002187
1	0·001442	0·0000519
	Head for 10 cubic feet per minute.	
1¼	0·04725	0·001701
1½	0·01899	0·000684
1¾	0·00878	0·000326
2	0·00451	0·000162
2¼	0·00250	0·000090
2½	0·00148	0·0000532
	Head for 100 cubic feet per minute.	
3	0·0594	0·00214
3½	0·0746	0·000989
4	0.0141	0·000507
4½	0·00782	0.000281
5	0·00462	0·000166
6	0·00186	0·0000668
7	0·000858	0·0000309
8	0·000440	0·0000158

Diameter of pipe in inches.	Head or difference of pressure at the two ends of pipe one yard long in	
	Inches of water.	Pounds per square inch.
	Head for 1000 cubic feet per minute.	
9	0·02442	0·000879
10	0·01442	0·000519
12	0·00579	0·000209
15	0·00189	0·0000681
18	0·000763	0·0000275
21	0·000353	0·0000127
24	0·000181	0·00000653
	Head for 10,000 cubic feet per minute.	
30	0·00593	0·000214
33	0·00368	0·000133
36	0·00238	0·0000858
42	0·001103	0·0000398
48	0·000566	0·0000204
54	0·000314	0·0000113
60	0·000185	0·00000669

TABLE II.—FRICTION OF WATER IN PIPES 100 FEET LENGTH.

Internal diameter of pipe in inches.										
		3			3½			4		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·659	36·7	5·89	·565	50·0	8·02	·494	64·8	10·4
2·2	·075	·780	40·4	6·48	·669	55·0	8·82	·585	71·7	11·5
2·4	·090	·911	44·1	7·07	·781	60·0	9·62	·683	78·0	12·5
2·6	·105	1·05	47·7	7·65	·901	64·8	10·4	·788	84·8	13·6
2·8	·122	1·20	52·4	8·24	1·03	69·8	11·2	·900	91·1	14·6
3·0	·140	1·35	55·0	8·83	1·16	74·8	12·0	1·02	97·9	15·7
3·2	·160	1·52	58·7	9·42	1·31	79·8	12·8	1·14	104	16·7
3·4	·180	1·70	62·4	10·0	1·46	84·8	13·6	1·27	111	17·8
3·6	·202	1·89	66·1	10·6	1·62	89·8	14·4	1·41	117	18·8
3·8	·225	2·08	69·8	11·2	1·78	94·8	15·2	1·56	124	19·9
4·0	·250	2·28	73·6	11·8	1·96	99·8	16·0	1·71	130	20·9
4·2	·275	2·49	76·7	12·3	2·14	104	16·8	1·87	137	22·0
4·4	·302	2·71	80·4	12·9	2·33	109	17·6	2·03	143	23·0
4·6	·330	2·94	84·2	13·5	2·52	114	18·4	2·21	149	24·0
4·8	·360	3·18	87·9	14·1	2·72	119	19·2	2·38	156	25·1
5·0	·390	3·43	91·7	14·7	2·94	124	20·0	2·57	163	26·2
5·2	·422	3·68	95·4	15·3	3·15	129	20·8	2·76	169	27·2
5·4	·455	3·94	99·2	15·9	3·38	134	21·6	2·96	175	28·2
5·6	·490	4·22	102	16·5	3·61	139	22·4	3·16	182	29·3
5·8	·525	4·50	106	17·1	3·85	144	23·2	3·37	189	30·3
6·0	·562	4·78	110	17·7	4·10	149	24·0	3·59	195	31·4
6·2	·600	5·08	113	18·2	4·36	154	24·8	3·81	202	32·4
6·4	·640	5·39	117	18·8	4·62	159	25·6	4·04	209	33·5
6·6	·680	5·70	121	19·4	4·89	164	26·4	4·28	215	34·5
6·8	·722	6·02	124	20·0	5·16	169	27·3	4·52	222	35·6
7·0	·765	6·35	128	20·6	5·45	174	28·0	4·77	228	36·6

TABLE II (*Continued*).

Internal diameter of pipe in inches.							
		4½			5		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·439	82·3	13·2	·395	101	16·3
2·2	·075	·520	91·1	14·6	·468	112	18·0
2·4	·090	·607	99·2	15·9	·547	122	19·6
2·6	·105	·701	107	17·2	·631	132	21·3
2·8	·122	·800	115	18·5	·720	142	22·9
3·0	·140	·905	123	19·8	·815	152	24·5
3·2	·160	1·02	132	21·2	·915	163	26·2
3·4	·180	1·13	140	22·5	1·02	173	27·8
3·6	·202	1·26	148	23·8	1·13	183	29·4
3·8	·225	1·39	157	25·2	1·25	193	31·0
4·0	·250	1·52	165	26·5	1·37	204	32·7
4·2	·275	1·66	173	27·8	1·50	214	34·3
4·4	·302	1·81	181	29·1	1·63	224	36·0
4·6	·330	1·96	189	30·4	1·76	234	37·6
4·8	·360	2·12	198	31·8	1·91	244	39·2
5·0	·390	2·28	206	33·1	2·05	255	40·9
5·2	·422	2·45	214	34·4	2·21	265	42·5
5·4	·455	2·63	223	35·8	2·37	275	44·2
5·6	·490	2·81	231	37·1	2·53	285	45·8
5·8	·525	3·00	239	38·4	2·70	295	47·4
6·0	·562	3·19	247	39·7	2·87	305	49·0
6·2	·600	3·39	255	41·0	3·05	316	50·7
6·4	·640	3·59	264	42·4	3·23	326	52·3
6·6	·680	3·80	272	43·7	3·42	336	54·0
6·8	·722	4·01	280	45·0	3·61	346	55·6
7·0	·765	4·24	289	46·4	3·81	356	57·2

TABLE II (*Continued*).

Internal diameter of pipe in inches.										
		6			7			8		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·329	146	23·5	·282	199	32·0	·247	261	41·9
2·2	·075	·390	161	25·9	·334	220	35·3	·293	287	46·1
2·4	·090	·456	175	28·2	·390	240	38·5	·342	313	50·2
2·6	·105	·526	190	30·6	·450	260	41·7	·394	339	54·4
2·8	·122	·600	205	32·9	·514	280	44·9	·450	365	58·6
3·0	·140	·679	220	35·3	·582	300	48·1	·509	391	62·8
3·2	·160	·763	235	37·7	·654	320	51·3	·572	418	67·0
3·4	·180	·851	249	40·0	·729	340	54·5	·638	444	71·2
3·6	·202	·943	264	42·4	·808	360	57·7	·707	470	75·4
3·8	·225	1·04	278	44·7	·892	380	60·9	·780	496	79·6
4·0	·250	1·14	293	47·1	·979	399	64·1	·856	522	83·7
4·2	·275	1·25	308	49·5	1·07	419	67·3	·935	548	87·9
4·4	·302	1·35	313	51·8	1·16	439	70·5	1·02	574	92·1
4·6	·330	1·47	337	54·1	1·26	459	73·7	1·10	600	96·3
4·8	·360	1·59	352	56·5	1·36	479	76·9	1·19	624	100
5·0	·390	1·71	367	58·9	1·47	499	80·2	1·28	655	105
5·2	·422	1·84	381	61·2	1·58	519	83·3	1·38	680	109
5·4	·455	1·97	396	63·6	1·69	540	86·6	1·48	705	113
5·6	·490	2·11	411	65·9	1·81	560	89·8	1·58	730	117
5·8	·525	2·25	426	68·3	1·93	580	93·0	1·68	755	121
6·0	·562	2·39	441	70·7	2·05	600	96·2	1·79	780	125
6·2	·600	2·54	455	73·0	2·18	620	99·4	1·90	811	130
6·4	·640	2·69	470	75·4	2·31	636	102	2·02	836	134
6·6	·680	2·85	484	77·7	2·44	661	106	2·14	861	138
6·8	·722	3·01	499	80·1	2·58	680	109	2·26	886	142
7·0	·765	3·18	514	82·4	2·72	698	112	2·38	911	146

TABLE II (*Continued*).

Internal diameter of pipe in inches.							
		9			10		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·220	330	53·0	·198	408	65·4
2·2	·075	·260	363	58·3	·234	449	72·0
2·4	·090	·304	396	63·6	·273	489	78·5
2·6	·105	·350	429	68·9	·315	531	85·1
2·8	·122	·400	463	74·2	·360	571	91·6
3·0	·140	·453	496	79·5	·407	612	98·2
3·2	·160	·508	529	84·8	·458	655	105
3·4	·180	·567	562	90·1	·510	692	111
3·6	·202	·629	595	95·4	·566	736	118
3·8	·225	·693	630	101	·624	773	124
4·0	·250	·761	661	106	·685	817	131
4·2	·275	·832	692	111	·748	854	137
4·4	·302	·905	723	116	·814	898	144
4·6	·330	·981	761	122	·883	936	150
4·8	·360	1·06	792	127	·954	979	157
5·0	·390	1·14	823	132	1·03	1017	163
5·2	·422	1·23	861	138	1·10	1060	170
5·4	·455	1·31	892	143	1·18	1104	177
5·6	·490	1·40	923	148	1·26	1141	183
5·8	·525	1·50	960	154	1·35	1185	190
6·0	·562	1·59	992	159	1·43	1223	196
6·2	·600	1·69	1023	164	1·52	1266	203
6·4	·640	1·79	1054	169	1·61	1304	209
6·6	·680	1·90	1092	175	1·71	1347	216
6·8	·722	2·01	1123	180	1·81	1385	222
7·0	·765	2·12	1144	185	1·90	1428	229

TABLE II (*Continued*).

Internal diameter of pipe in inches.										
		11			12			13		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·180	494	72·2	·165	587	94·2	·152	686	110
2·2	·075	·213	543	87·1	·195	642	103	·180	755	121
2·4	·090	·248	592	95·0	·228	705	113	·210	829	133
2·6	·105	·287	642	103	·263	761	122	·242	898	144
2·8	·122	·327	692	111	·300	823	132	·277	973	156
3·0	·140	·370	742	119	·339	879	141	·313	1035	166
3·2	·160	·416	792	127	·381	942	151	·352	1104	177
3·4	·180	·464	836	134	·425	998	160	·393	1173	188
3·6	·202	·514	886	142	·472	1054	169	·435	1241	199
3·8	·225	·567	936	150	·520	1116	179	·480	1310	210
4·0	·250	·623	985	158	·571	1173	188	·527	1379	221
4·2	·275	·680	1035	166	·624	1235	198	·576	1447	232
4·4	·302	·740	1085	174	·679	1291	207	·626	1516	243
4·6	·330	·803	1135	182	·736	1354	217	·679	1584	254
4·8	·360	·867	1185	190	·795	1410	226	·734	1653	265
5·0	·390	·935	1235	198	·857	1466	235	·791	1722	276
5·2	·422	1·00	1285	206	·920	1528	245	·850	1790	287
5·4	·455	1·07	1335	214	·986	1584	254	·910	1859	298
5·6	·490	1·15	1385	222	1·05	1647	264	·973	1928	309
5·8	·525	1·22	1428	229	1·12	1703	273	1·04	2003	321
6·0	·562	1·30	1478	237	1·19	1765	283	1·10	2071	332
6·2	·600	1·38	1528	245	1·27	1822	292	1·17	2140	343
6·4	·640	1·47	1578	253	1·35	1878	301	1·24	2208	354
6·6	·680	1·55	1628	261	1·42	1940	311	1·31	2277	365
6·8	·722	1·64	1678	269	1·50	1996	320	1·39	2346	376
7·0	·765	1·73	1728	277	1·59	2059	330	1·46	2414	387

Table II (*Continued*).

Internal diameter of pipe in inches.							
		14			15		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·141	798	128	·132	917	147
2·2	·075	·167	879	141	·156	1010	162
2·4	·090	·195	950	154	·182	1098	176
2·6	·105	·225	1042	167	·210	1191	191
2·8	·122	·257	1116	179	·240	1285	206
3·0	·140	·291	1235	198	·271	1379	221
3·2	·160	·327	1279	205	·305	1466	235
3·4	·180	·365	1360	218	·340	1560	250
3·6	·202	·404	1441	231	·377	1653	265
3·8	·225	·446	1516	243	·416	1747	280
4·0	·250	·489	1597	256	·457	1834	294
4·2	·275	·534	1678	269	·499	1928	309
4·4	·302	·582	1759	282	·543	2021	324
4·6	·330	·634	1830	295	·589	2115	339
4·8	·360	·682	1921	308	·636	2202	353
5·0	·390	·734	2003	321	·685	2296	368
5·2	·422	·789	2077	333	·736	2389	383
5·4	·455	·845	2159	346	·789	2471	397
5·6	·490	·903	2240	359	·843	2570	412
5·8	·525	·964	2321	372	·899	2664	427
6·0	·562	1·02	2402	385	·957	2758	442
6·2	·600	1·09	2477	397	1·01	2845	456
6·4	·640	1·15	2558	410	1·08	2939	471
6·6	·680	1·22	2639	423	1·14	3032	486
6·8	·722	1·29	2720	436	1·20	3120	500
7·0	·765	1·36	2801	449	1·27	3213	515

TABLE II (*Continued*).

Internal diameter of pipe in inches.										
		16			18			20		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·123	1042	167	·110	1322	212	·099	1634	262
2·2	·075	·146	1148	184	·130	1493	233	·117	1797	288
2·4	·090	·171	1254	201	·152	1584	254	·137	1959	314
2·6	·105	·197	1360	218	·175	1716	275	·158	2121	340
2·8	·122	·225	1460	234	·200	1853	297	·180	2283	366
3·0	·140	·255	1566	251	·226	1984	318	·204	2452	393
3·2	·160	·286	1672	268	·254	2115	339	·229	2614	419
3·4	·180	·319	1772	284	·283	2246	360	·255	2776	445
3·6	·202	·354	1878	301	·314	2383	382	·283	2939	471
3·8	·225	·390	1984	318	·347	2514	403	·312	3101	497
4·0	·250	·428	2090	335	·380	2645	424	·342	3263	523
4·2	·275	·468	2196	352	·416	2776	445	·374	3432	550
4·4	·302	·509	2296	368	·452	2907	466	·407	3594	576
4·6	·330	·552	2402	385	·490	3045	488	·441	3756	602
4·8	·360	·596	2508	402	·530	3176	509	·477	3918	628
5·0	·390	·642	2614	419	·571	3307	530	·514	4080	654
5·2	·422	·690	2714	435	·614	3438	551	·552	4243	680
5·4	·455	·740	2820	452	·657	3569	572	·592	4411	707
5·6	·490	·791	2926	469	·703	3706	594	·632	4573	733
5·8	·525	·843	3032	486	·749	3837	615	·674	4736	759
6·0	·562	·897	3132	502	·798	3968	636	·718	4898	785
6·2	·600	·953	3238	519	·847	4099	657	·762	5060	811
6·4	·640	1·01	3344	536	·898	4230	678	·808	5229	838
6·6	·680	1·07	3450	553	·950	4368	700	·855	5391	864
6·8	·722	1·13	3550	569	1·00	4499	721	·904	5553	890
7·0	·765	1·19	3656	586	1·06	4630	742	·953	5715	916

TABLE II (*Continued*).

Internal diameter of pipe in inches.							
		22			24		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·090	1971	316	·082	2352	377
2·2	·075	·106	2171	348	·097	2583	414
2·4	·090	·124	2371	380	·114	2820	452
2·6	·105	·143	2570	412	·131	3057	490
2·8	·122	·164	2764	443	·150	3294	528
3·0	·140	·185	2964	475	·170	3525	565
3·2	·160	·208	3163	507	·191	3762	603
3·4	·180	·232	3357	538	·213	3999	641
3·6	·202	·257	3556	570	·236	4230	678
3·8	·225	·284	3750	601	·260	4467	716
4·0	·250	·311	3949	633	·285	4704	754
4·2	·275	·340	4149	665	·312	4935	791
4·4	·302	·370	4349	697	·339	5172	829
4·6	·330	·401	4542	728	·368	5410	867
4·8	·360	·434	4742	760	·397	5647	905
5·0	·390	·467	4942	792	·428	5878	942
5·2	·422	·502	5135	823	·460	6075	980
5·4	·455	·538	5335	855	·493	6352	1018
5·6	·490	·575	5534	887	·527	6583	1055
5·8	·525	·613	5728	918	·562	6820	1093
6·0	·562	·652	5928	950	·598	7057	1131
6·2	·600	·693	6127	982	·635	7288	1168
6·4	·640	·735	6321	1013	·673	7525	1206
6·6	·680	·778	6520	1045	·713	7762	1244
6·8	·722	·821	6720	1077	·753	7999	1282
7·0	·765	·867	6920	1109	·794	8230	1319

TABLE II (*Continued*).

		Internal diameter of pipe in inches.								
		26			28			30		
Velocity of water in feet per second.	Head to produce this velocity in feet.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.	Head to overcome friction in feet.	Gallons per minute.	Cubic feet per minute.
2·0	·062	·076	2758	442	·070	3201	513	·066	3675	589
2·2	·075	·090	3032	486	·083	3519	564	·078	4043	684
2·4	·090	·105	3313	531	·097	3843	616	·091	4411	707
2·6	·105	·121	3588	575	·112	4162	667	·105	4789	766
2·8	·122	·138	3862	619	·128	4480	718	·120	5141	824
3·0	·140	·157	4137	663	·145	4804	770	·136	5509	883
3·2	·160	·176	4417	708	·163	5123	821	·152	5878	942
3·4	·180	·196	4692	752	·182	5441	872	·170	6246	1001
3·6	·202	·218	4967	796	·202	5759	923	·189	6614	1060
3·8	·225	·240	5241	840	·223	6077	974	·208	6982	1119
4·0	·250	·263	5522	885	·244	6402	1026	·228	7350	1178
4·2	·275	·288	5796	929	·267	6720	1077	·249	7718	1237
4·4	·302	·313	6071	973	·290	7044	1129	·271	8087	1296
4·6	·330	·339	6346	1017	·315	7363	1180	·294	8455	1355
4·8	·360	·367	6626	1062	·341	7681	1231	·318	8823	1414
5·0	·390	·395	6901	1106	·367	8005	1283	·343	9185	1472
5·2	·422	·425	7176	1150	·394	8324	1334	·368	9553	1531
5·4	·455	·455	7450	1194	·423	8642	1385	·394	9921	1590
5·6	·490	·486	7731	1239	·452	8966	1437	·422	10289	1649
5·8	·525	·519	8005	1283	·482	9285	1488	·450	10657	1708
6·0	·562	·552	8280	1327	·513	9603	1539	·478	11026	1767
8·2	·600	·586	8555	1371	·544	9921	1590	·508	11394	1826
6·4	·640	·622	8835	1416	·577	10246	1642	·539	11762	1885
6·6	·680	·658	9110	1460	·611	10564	1693	·570	12124	1943
6·8	·722	·695	9384	1504	·645	10882	1744	·602	12498	2003
7·0	·765	·733	9659	1548	·681	11207	1796	·635	12860	2061

TABLE III.—FLOW OF STEAM THROUGH PIPES.

("Steam.")

Initial pressure per square inch in lbs.	Diameter of pipe in inches, length of each pipe 240 diameters.													
	¾	1	1½	2	2½	3	4	5	6	8	10	12	15	18
	Weight of steam per minute in pounds, with one pound fall of pressure.													
1	1·16	2·07	5·7	10·27	15·45	25·38	46·85	77·3	115·9	211·4	341·1	502·4	804	1177
10	1·44	2·57	7·1	12·72	19·15	31·45	48·05	95·8	143·6	262·0	422·7	622·5	996	1458
20	1·70	3·02	8·3	14·94	22·49	36·94	68·20	112·6	168·7	307·8	496·5	731·3	1170	1713
30	1·91	3·40	9·4	16·84	25·35	41·63	76·84	126·9	190·1	346·8	559·5	824·1	1318	1930
40	2·10	3·74	10·3	18·51	27·87	45·77	84·49	139·5	209·0	381·3	615·3	906·0	1450	2122
50	2·27	4·04	11·2	20·01	30·13	49·48	91·34	150·8	226·0	412·2	665·0	979·5	1567	2294
60	2·43	4·32	11·9	21·38	32·19	52·87	97·60	161·1	241·5	440·5	710·6	1046·7	1675	2451
70	2·57	4·58	12·6	22·65	34·10	56·00	103·37	170·7	255·8	466·5	752·7	1108·5	1774	2596
80	2·71	4·82	13·3	23·82	35·87	58·91	108·74	179·5	269·0	490·7	791·7	1166·1	1866	2731
90	2·83	5·04	13·9	24·92	37·52	61·62	113·74	187·8	281·4	513·3	828·1	1219·8	1951	2856
100	2·95	5·25	14·5	25·96	39·07	64·18	118·47	195·6	293·1	534·6	862·6	1270·1	2032	2975
120	3·16	5·63	15·5	27·85	41·93	68·87	127·12	209·9	314·5	573·7	925·6	1363·3	2181	3193
150	3·45	6·14	17·0	30·37	45·72	75·09	133·61	228·8	343·0	625·5	1009·2	1486·5	2378	3481

TABLE IV.—BRANCH PIPES OF EQUAL AREA TO THE MAIN PIPE.

Diameter of main pipe, inches.	Diameter of branch pipes in inches.														
	¼	⅜	½	¾	1	1¼	1½	1¾	2	2½	3	3½	4	4½	5
	Number of branch pipes.														
1	16	7	4												
1¼	25	11	6	2											
1½	36	16	9	4	2										
1¾	49	21	12	5	3										
2	64	28	16	7	4	2									
2½	100	44	25	11	6	4	2								
3	144	64	35	16	9	5	4	2							
3½	196	87	49	21	12	7	5	4	3						
4	256	113	64	28	16	10	7	5	4	2					
4½	324	144	81	36	20	12	9	6	5	3	2				
5	400	177	100	44	25	16	11	8	6	4	2				
6	577	256	144	64	36	23	16	11	9	5	4	2			
7	785	348	196	87	49	31	21	16	12	7	5	4	3	2	
8	1024	456	256	112	64	40	28	20	16	10	7	5	4	3	2
9	1298	576	324	144	80	51	36	26	20	12	9	6	5	4	3
10	1600	702	400	177	100	64	44	32	25	16	11	8	6	5	4
11	1939	860	484	215	120	77	53	39	30	19	13	9	7	6	4
12	2304	1024	576	256	144	92	64	47	36	23	16	11	9	7	5
13	2708	1202	676	300	169	108	75	55	42	27	18	13	10	8	6
14	3141	1394	784	348	196	125	87	64	49	31	21	16	12	9	7

15	3606	1600	900	400	225	144	100	73	56	36	25	18	14	11	9
16	4096	1823	1024	455	256	163	112	83	64	40	28	20	16	12	10
17	4632	2055	1156	513	288	184	128	94	72	46	32	23	18	14	11
18	5193	2304	1296	576	324	207	144	105	81	51	36	26	20	16	12
19	5786	2568	1444	641	361	231	160	117	90	57	40	29	22	17	14
20	6411	2849	1600	711	400	256	177	130	100	64	44	32	25	19	16
21	7068	3137	1764	784	441	282	196	144	110	70	49	36	27	21	17
22	7757	3443	1936	860	484	309	215	158	121	77	53	39	30	23	19
23	8479	3763	2111	940	529	338	235	172	132	84	58	43	33	26	21
24	9216	4097	2304	1024	576	368	256	188	144	92	64	47	36	28	23
25	—	4446	2500	1111	625	400	277	204	156	100	69	51	39	30	25
26	—	4809	2704	1202	676	432	300	220	169	108	75	55	42	33	27
27	—	5186	2916	1295	728	466	324	238	182	116	81	59	45	36	29
28	—	5577	3136	1394	784	501	348	256	196	125	87	64	49	38	31
29	—	5982	3364	1495	843	538	373	274	210	134	93	68	52	41	33
30	—	6400	3600	1600	900	576	400	293	225	144	100	73	56	43	36
31	—	6836	3845	1708	961	615	428	313	240	153	106	78	60	47	38
32	—	7284	4096	1820	1024	655	455	334	256	163	113	83	64	50	40
33	—	7747	4357	1936	1088	697	484	355	272	174	121	88	68	53	43
34	—	8223	4625	2054	1156	739	513	377	289	184	128	94	72	57	46
35	—	8714	4901	2178	1225	784	544	400	306	196	136	100	76	60	49
36	—	9216	5189	2304	1297	829	576	423	324	207	144	105	81	64	51
37	—	9739	5477	2434	1368	877	608	447	342	217	152	111	85	67	54
38	—	—	5777	2567	1443	924	641	471	360	231	160	117	90	71	57
39	—	—	6085	2704	1520	973	676	496	380	243	169	124	95	75	60
40	—	—	6401	2845	1600	1024	711	522	400	256	177	130	100	79	64

TABLE IV (*Continued*).

Diameter of main pipe, inches.	Diameter of branch pipes in inches.														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Number of branch pipes.														
1															
1¼															
1½															
1¾															
2															
2½															
3															
3½															
4															
4½															
5															
6															
7															
8															
9	2														
10	3	2													
11	3	2													
12	4	3	2												
13	4	3	2												
14	5	4	3	2											
15	6	4	3	2											
16	7	5	4	3	2	2									
17	8	5	4	3	2	2	2								
18	9	6	5	4	3	2	2								
19	10	7	5	4	3	2	2	2							
20	11	8	6	4	4	3	2	2	2						
21	12	9	6	5	4	3	2	2	2						
22	13	9	7	5	4	4	3	2	2	2					
23	14	10	8	6	5	4	3	3	2	2	2				
24	16	11	8	7	5	4	4	3	2	2	2				
25	17	12	9	7	6	5	4	3	3	2	2	2			
26	18	13	10	8	6	5	4	4	3	3	2	2	2		
27	20	14	11	9	7	6	5	4	3	3	2	2	2	2	
28	21	16	12	9	7	6	5	4	3	3	3	2	2	2	
29	23	17	13	10	8	6	5	4	4	3	3	2	2	2	2
30	25	18	14	11	9	7	6	5	4	4	3	3	2	2	2
31	26	19	15	11	9	7	6	5	4	4	3	3	2	2	2
32	28	20	16	12	10	8	7	6	5	4	4	3	3	2	2
33	30	22	17	13	10	9	7	6	5	4	4	3	3	3	2
34	32	23	18	14	11	9	8	6	5	5	4	4	3	3	2
35	34	25	19	15	12	10	8	7	6	5	4	4	3	3	3
36	36	26	20	16	12	10	9	7	6	5	5	4	4	3	3
37	38	27	21	16	13	11	9	8	6	6	5	4	4	3	3
38	40	29	22	17	14	11	10	8	7	6	5	4	4	4	3
39	42	31	23	18	15	12	10	9	7	6	5	5	4	4	3
40	44	32	25	19	16	13	11	9	8	7	6	5	4	4	4

TABLE IV (*Continued*).

Diameter of main pipe, inches.	Diameter of branch pipes in inches.							
	21	22	23	24	25	26	27	28
	Number of branch pipes.							
1								
1¼								
1½								
1¾								
2								
2½								
3								
3½								
4								
4½								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30	2							
31	2							
32	2	2						
33	2	2	2					
34	2	2	2	2				
35	2	2	2	2				
36	2	2	2	2	2			
37	3	2	2	2	2	2		
38	3	2	2	2	2	2		
39	3	3	2	2	2	2	2	
40	3	3	3	2	2	2	2	2

TABLE V.—WEIGHT OF CAST-IRON PIPES.

Bore of pipe in inches.	Thickness of metal in fractions of an inch.												
	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 1/4
	Weight of cast-iron flange pipes per foot run in lbs.												
1	3·1	4·0	5·1	6·2	7·4	8·6	10·0	11·4	12·9	16·1	19·6	23·4	27·6
1¼	3·7	4·8	6·0	7·2	8·6	10·0	11·5	13·1	14·7	18·2	22·1	26·2	30·7
1½	4·3	5·6	6·9	8·3	9·8	11·4	13·0	14·7	16·5	20·4	24·5	28·9	33·7
1¾	4·9	6·8	7·8	9·4	11·0	12·7	14·5	16·4	18·4	22·5	26·9	31·7	36·7
2			8·7	10·4	12·3	14·1	16·1	18·1	20·3	24·7	29·5	34·5	39·9
2¼			9·6	11·5	13·5	15·5	17·6	19·8	22·0	26·8	31·8	37·2	42·9
2½			10·6	12·6	14·7	16·9	19·1	21·5	23·9	28·9	34·3	40·0	45·9
2¾			11·5	13·7	16·0	18·3	20·7	23·2	25·7	31·1	36·8	42·7	49·0
3			12·4	14·7	17·1	19·6	22·2	24·8	27·6	33·3	39·3	45·5	52·0
3¼			13·3	15·8	18·4	21·0	23·7	26·5	29·4	35·4	41·6	48·2	55·1
3½			14·2	16·9	19·6	22·4	25·3	28·2	31·2	37·5	44·1	51·0	58·2
3¾			15·2	18·0	20·8	23·8	26·8	29·9	33·1	39·7	46·6	53·8	61·3
4			16·1	19·0	22·1	25·1	28·3	31·6	35·0	41·9	49·1	56·5	64·3
4¼			17·0	20·1	23·3	26·6	30·0	33·3	36·8	44·0	51·5	59·3	67·4
4½			17·9	21·2	24·5	27·9	31·4	34·9	38·6	46·1	53·9	62·0	70·4
4¾			18·8	22·3	25·7	29·3	33·0	36·6	40·4	48·2	56·3	64·8	73·5
5			19·8	23·3	26·9	30·7	34·4	38·3	42·3	50·5	58·8	65·7	76·6
5¼			20·7	24·4	28·2	32·0	36·0	40·0	44·1	52·5	61·3	70·3	79·7
5½			21·6	25·5	29·4	33·5	37·5	41·7	46·0	54·7	63·7	73·1	82·7
5¾			22·5	26·6	30·6	34·8	39·1	43·4	47·8	56·8	66·2	75·8	85·8
6			23·4	27·6	31·9	36·2	40·6	45·0	49·7	59·1	68·7	78·7	89·0
6¼			24·4	28·7	33·1	37·6	42·9	46·8	51·5	61·1	71·1	81·3	92·0
6½			25·3	29·7	34·3	38·9	44·2	48·4	53·3	63·2	73·5	84·1	95·0
6¾			26·2	30·8	35·5	40·3	45·2	50·1	55·1	65·4	76·0	86·8	98·0
7			27·1	31·9	36·8	41·7	46·7	51·8	56·8	67·7	78·5	89·7	101·2
7¼			28·0	32·9	37·7	43·1	48·2	53·5	58·8	69·7	80·9	92·4	104·1
7½			29·0	34·0	39·2	44·5	49·8	55·2	60·7	71·9	83·3	95·1	107·2
7¾			29·9	35·1	40·4	45·8	51·3	56·8	62·5	74·0	85·8	97·9	110·3

8			30·8	36·2	41·6	47·1	52·8	58·5	64·3	76·2	88·4	100·8	113·5
8½			32·8	38·2	44·1	50·0	56·0	61·9	68·0	80·4	93·1	106·1	119·5
9			34·4	40·5	46·6	52·7	58·9	65·3	71·7	84·8	98·2	111·8	125·8
9½			36·3	42·6	49·0	55·5	62·0	68·6	75·3	89·1	102·7	117·1	131·4
10			38·2	44·7	52·4	58·2	65·1	72·9	79·0	93·3	108·0	122·9	138·1
10½			40·0	46·8	53·7	60·9	68·0	75·2	82·4	97·4	112·7	128·3	143·9
11			41·9	48·9	56·4	63·6	71·0	78·5	86·4	101·8	117·8	133·9	150·3
11½			43·7	51·2	59·0	66·5	74·3	82·1	90·2	106·1	122·6	139·2	156·3
12			45·6	53·4	61·4	69·3	77·3	85·8	93·7	110·4	127·4	145·0	162·6
12½					63·6	72·1	80·2	88·9	97·3	114·5	132·3	150·2	168·5
13					66·1	74·6	83·3	92·0	101·1	118·9	137·3	155·7	174·4
13½					68·6	77·4	86·4	95·5	104·8	123·2	142·0	161·3	180·6
14					71·2	80·2	89·6	98·9	108·4	127·5	147·0	167·1	187·2
14½					73·3	83·0	92·7	102·3	111·2	131·7	149·9	172·2	192·8
15					76·1	85·8	95·9	105·5	115·7	136·1	156·8	177·7	199·4
15½					78·6	88·6	99·0	109·2	119·5	140·7	161·9	183·5	205·3
16					81·0	91·4	102·0	112·6	123·2	144·7	166·6	188·7	211·7
16½					83·3	93·9	104·8	115·8	126·7	148·8	171·6	194·4	217·5
17					85·8	97·0	108·0	119·2	130·7	153·5	176·6	199·0	223·7
17½					88·3	99·5	111·1	122·6	134·2	157·6	181·3	205·3	229·6
18					90·8	102·3	114·3	126·0	137·9	161·9	186·2	210·9	236·2
18½					93·0	104·8	117·0	129·2	141·3	166·0	190·9	216·2	241·6
19					95·5	108·0	120·1	132·6	145·1	170·4	195·9	221·8	248·0
19½					98·0	110·8	123·2	136·0	148·8	174·7	200·9	227·4	255·5
20					100·5	113·3	126·5	139·5	152·3	178·9	205·8	232·9	260·3
20½							129·5	142·9	156·3	183·5	210·9	238·4	266·4
21							132·6	146·3	160·1	187·5	215·6	244·0	272·6
21½							135·4	149·4	163·5	191·9	220·6	249·6	278·6
22							138·8	152·9	167·2	197·1	225·4	254·9	284·8
22½							141·6	156·0	170·7	200·8	230·3	260·5	290·8
23							144·8	159·7	174·7	205·0	235·3	266·1	297·3
23½							147·9	162·9	178·2	209·0	240·2	271·4	303·3
24							151·2	166·6	182·5	213·9	245·0	276·9	309·3

The weight of the two flanges is usually reckoned equal to the weight of one foot of pipe.

TABLE VI.—SOCKET PIPES (*not turned and bored*).
(*Fig.* 187.)

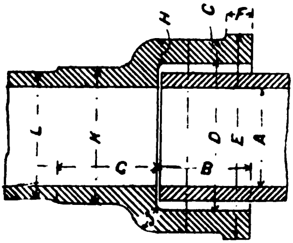

Fig. 187.

A inch.	B inch.	C inch.	D inch.	E inch.	F inch.	G inch.	H inch.	J inch.	K inch.	L inch.
2	3	3	3¼	5	¾	11/16	⅝	¾	3	2¾
3	3	3	4¼	6	¾	11/16	⅝	¾	4	3¾
4	3	3	5¼	7	¾	11/16	⅝	¾	5	4¾
5	3½	3½	6⅝	8⅝	⅞	13/16	11/16	⅞	6¼	5⅞
6	3½	3½	7⅝	9⅝	⅞	13/16	11/16	⅞	7¼	6⅞
7	3½	3½	8¾	10¾	⅞	13/16	11/16	⅞	8¼	8
8	4	4	9¾	12	1	13/16	11/16	⅞	9¼	9
9	4	4	10⅞	13⅛	1	13/16	11/16	⅞	10½	10⅛
12	4	4	14	16½	1	15/16	13/16	1⅛	13½	13¼
15	4½	4½	17⅛	19⅞	1⅛	1 1/16	15/16	1¼	16¾	16⅜
18	4½	4½	20⅜	23⅜	1¼	1⅛	1	1¼	20	19⅝
20	4½	4½	22½	25¾	1⅜	1¼	1⅛	1¼	22¼	21¾
24	5	5	26¾	30¼	1½	1⅜	1¼	1½	26¼	26
33	5½	5	35¾	37¾	1¾	1½	1⅜	1⅝	35⅝	35

TABLE VII.—SOCKET PIPES (*turned and bored*). (*Fig.* 188.)

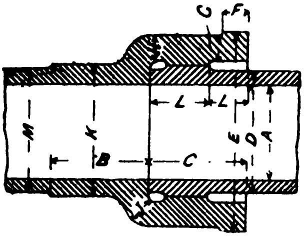

Fig. 188.

A inch.	B inch.	C inch.	D inch.	E inch.	F inch.	G inch.	H inch.	J inch.	K inch.	L inch.	M inch.
2	3	3¼	3¼	5	¾	11/16	⅝	¾	3	1¼	2¾
3	3	3	4¼	6	¾	11/16	⅝	¾	4	1¼	3¾
4	3	3	5¼	7	¾	11/16	⅝	¾	5	1¼	4¾
5	3½	3½	6⅝	8⅝	⅞	13/16	11/16	⅞	6¼	1⅜	5⅞
6	3½	3½	7⅝	9⅝	⅞	13/16	11/16	⅞	7¼	1⅜	6⅞
7	3½	3½	8¾	10¾	⅞	13/16	11/16	⅞	8¼	1⅜	8
8	4	4	9¾	12	1	13/16	11/16	⅞	9¼	1⅝	9
9	4	4	10⅞	13⅛	1	13/16	11/16	⅞	10½	1⅝	10⅛
12	4½	4½	14	16½	1	15/16	13/16	1	13½	1¾	13¼

The taper of the bored portions is $\frac{1}{32}$ inch per inch in length.

TABLE VIII.—PROPORTIONS OF CAST-IRON FLANGES ON CAST-IRON PIPES. (*Fig.* 189.)

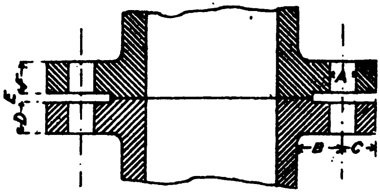

Fig. 189.

A	B	C	D	E	F
inches.	inches.	inches.	inches.	inches.	inches.
½	1	⅞	¾	¼	¾
⅝	1⅛	⅞	⅞	¼	⅞
¾	1¼	1	1	¼	1
⅞	1⅜	1⅛	1⅛	¼	1⅛
1	1½	1¼	1¼	¼	1¼
1⅛	1⅝	1⅜	1⅜	¼	1⅜
1¼	1¾	1½	1⅝	⅜	1⅝
1½	2	1¾	1⅞	½	1⅞
1¾	2¼	2	2¼	½	2¼
2	2½	2¼	2½	½	2½

TABLE IX.—PROPORTIONS OF FLANGES FOR WROUGHT-IRON PIPES. (*Fig.* 190.)

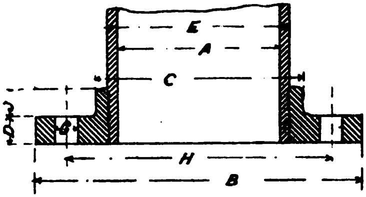

Fig. 190.

A in.	B in.	C in.	D For wrought iron. inches.	D For cast-iron. ins.	E ins.	F Thickness of cast-iron pipe. inches.	G Diameter of bolt. inches.	Number of bolts.	H Pitch of bolts. inches.	J in.
1	4¾	2	½	9/16	1 5/16	½	½	3	3½	½
1¼	5	2¼	½	9/16	1⅝	½	½	3	3¾	½
1½	5¼	2½	½	⅝	1 7/16	½	½	4	4	½
1¾	6	2¾	½	⅝	2 3/32	½	⅝	4	4½	½
2	6¼	3	9/16	11/16	2 5/16	½	⅝	4	4¾	9/16
2¼	6¾	3¼	9/16	11/16	2⅝	½	⅝	4	5⅛	9/16
2½	7	3⅝	9/16	11/16	2 15/16	½	⅝	4	5⅜	9/16
2¾	7¼	3⅞	9/16	11/16	3 3/16	½	⅝	4	5⅝	9/16
3	7¾	4¼	⅝	¾	3 7/16	½	⅝	4	6	⅝
3¼	8	4½	⅝	¾	3¾	9/16	⅝	4	6¼	⅝
3½	8½	4¾	⅝	¾	4	9/16	¾	4	6¾	⅝
3¾	8¾	5	⅝	¾	4¼	9/16	¾	5	7	⅝
4	9	5¼	¾	⅞	4½	9/16	¾	5	7¼	¾
4¼	9¼	5½	¾	⅞	4¾	9/16	¾	5	7½	¾
4½	9½	5¾	¾	⅞	5	9/16	¾	6	7¾	¾
5	10	6¼	¾	1	5½	⅝	¾	6	8¼	¾
5½	10½	6¾	¾	1	6	⅝	¾	6	8¾	¾
6	11	7¼	¾	1	6½	⅝	¾	8	9¼	¾
6½	11½	7¾	¾	1	7	⅝	¾	8	9¾	¾
7	12¼	8¼	¾	1⅛	7½	⅝	¾	8	10¼	¾
7½	12½	8¾	¾	1⅛	8	⅝	¾	8	10¾	¾
8	13	9¼	¾	1⅛	8½	⅝	¾	8	11¼	¾
8½	13½	9¾	¾	1⅛	9	⅝	¾	8	11¾	¾
9	14	10¼	¾	1⅛	9½	⅝	¾	8	12¼	¾
9½	14½	10¾	¾	1⅛	10	⅝	¾	8	12¾	¾
10	15½	11¼	⅞	1¼	10½	⅝	⅞	8	13½	⅞
10½	16	11¾	⅞	1¼	11	⅝	⅞	8	14	⅞
11	16½	12¼	⅞	1¼	11½	⅝	⅞	8	14½	⅞
11½	17¼	13	⅞	1¼	12	⅝	⅞	8	15¼	⅞
12	18½	13⅝	1	1⅜	12½	⅝	1	10	16⅛	1

TABLE X.—PROPORTIONS OF HEAVY OVAL FLANGES (*Cast-iron*). (*Fig.* 191.)

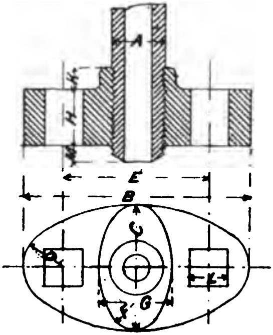

Fig. 191.

Bore. in.	A in.	B in.	C in.	D in.	E in.	F in.	G in.	H in.	K in.	L in.	M in.	Size of bolt. inches.
$\frac{1}{2}$	$1\frac{3}{16}$	$3\frac{1}{2}$	$1\frac{3}{4}$	$\frac{5}{8}$	$2\frac{1}{4}$	$\frac{7}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{1}{2}$
$\frac{5}{8}$	$1\frac{1}{16}$	5	$2\frac{1}{2}$	$\frac{13}{16}$	$3\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{8}$	$\frac{11}{16}$	$\frac{1}{8}$	$\frac{5}{8}$
$\frac{3}{4}$	$1\frac{5}{16}$	$5\frac{1}{2}$	$2\frac{3}{4}$	$\frac{7}{8}$	$3\frac{3}{4}$	$\frac{3}{4}$	2	$1\frac{3}{8}$	$\frac{7}{16}$	$\frac{11}{16}$	$\frac{3}{16}$	$\frac{5}{8}$
1	$1\frac{9}{16}$	$6\frac{1}{4}$	3	$\frac{7}{8}$	$4\frac{1}{8}$	$\frac{7}{8}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{5}{8}$	$\frac{13}{16}$	$\frac{3}{16}$	$\frac{3}{4}$
$1\frac{1}{4}$	$1\frac{7}{8}$	$6\frac{1}{2}$	$3\frac{1}{2}$	1	$4\frac{1}{2}$	1	$2\frac{5}{8}$	$1\frac{5}{8}$	$\frac{5}{8}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{4}$
$1\frac{1}{2}$	$2\frac{1}{16}$	$7\frac{1}{4}$	4	$1\frac{1}{8}$	$5\frac{1}{8}$	$1\frac{1}{8}$	3	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{15}{16}$	$\frac{1}{4}$	$\frac{7}{8}$
$1\frac{3}{4}$	$2\frac{5}{16}$	$8\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$5\frac{3}{4}$	$1\frac{5}{16}$	$3\frac{1}{2}$	$1\frac{7}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{5}{16}$	$\frac{7}{8}$
2	$2\frac{9}{16}$	9	5	$1\frac{13}{16}$	$6\frac{1}{2}$	$1\frac{3}{4}$	4	2	1	$1\frac{1}{16}$	$\frac{3}{8}$	1

These flanges are suitable for pressures up to about 1500 lbs. per square inch.

TABLE XI.—PROPORTIONS OF LIGHT OVAL FLANGES (*Cast-iron*). (*Fig.* 191.)

Bore. in.	A in.	B in.	C in.	D in.	E in.	F in.	G in.	H in.	K in.	L in.	M in.	Size of bolt. inches.
1	$1\frac{5}{16}$	5	$2\frac{1}{2}$	$\frac{13}{16}$	$3\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{11}{16}$	$\frac{3}{16}$	$\frac{5}{8}$
$1\frac{1}{4}$	$1\frac{9}{16}$	$5\frac{1}{2}$	$2\frac{3}{4}$	$\frac{7}{8}$	$3\frac{3}{4}$	$\frac{3}{4}$	2	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{11}{16}$	$\frac{1}{4}$	$\frac{5}{8}$
$1\frac{1}{2}$	$1\frac{15}{16}$	$6\frac{1}{4}$	3	$\frac{7}{8}$	$4\frac{1}{8}$	$\frac{7}{8}$	$2\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{4}$
$1\frac{3}{4}$	$2\frac{1}{16}$	$6\frac{1}{2}$	$3\frac{1}{2}$	1	$4\frac{1}{2}$	1	$2\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{8}$	$\frac{13}{16}$	$\frac{1}{4}$	$\frac{3}{4}$
2	$2\frac{5}{16}$	$7\frac{1}{4}$	4	$1\frac{1}{8}$	$5\frac{1}{8}$	$1\frac{1}{8}$	3	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{15}{16}$	$\frac{1}{4}$	$\frac{7}{8}$
$2\frac{1}{2}$	$2\frac{15}{16}$	$8\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$5\frac{3}{4}$	$1\frac{5}{16}$	$3\frac{1}{2}$	$1\frac{3}{8}$	$\frac{9}{16}$	$\frac{15}{16}$	$\frac{1}{4}$	$\frac{7}{8}$

TABLE XII.—COMPARATIVE WEIGHTS OF PIPES PER LINEAL FOOT.

Diameter of pipe in inches.	Spirally-welded steel and iron pipes.						Lap-welded iron. Standard lbs.	Cast-iron.		
	No. 18 Gauge lbs.	No. 16 Gauge lbs.	No. 14 Gauge lbs.	No. 12 Gauge lbs.	No. 10 Gauge lbs.	No. 8 Gauge lbs.		Thickness ½ inch. lbs.	Thickness ⅝ inch. lbs.	Thickness ¾ inch. lbs.
4	2·06	2·73					10·72	22·05	28·28	34·94
5	2·58	3·42					14·56	26·94	34·34	42·38
6	3·09	4·10	5·20				18·77	31·82	40·56	49·6
8	4·13	5·47	6·98				28·35	41·64	52·68	64·27
10	5·16	6·83	8·72	11.44	14·08		40·64	51·46	65·08	78·99
12	6·18	8·20	10·46	13·74	16·90	20·80	54·65	61·27	77·36	93·7
14	7·22	9·57	12·20	16·02	19·72	24·86		71·07	89·61	108·46
16	8·25	10·93	13·95	18·30	22·54	27·72		80·87	101·82	123·14
								Thickness ⅝ inch.	Thickness ¾ inch.	Thickness ⅞ inch.
18	9·28	12·30	15·69	20·69	25·35	31·19		114·1	137·84	161·9
20		13·66	17·44	22·28	28·16	34·66		126·33	152·53	179·02
22		15·03	19·18	25·27	30·98	38·12		138·6	167·24	196·46
24		16·40	20·92	27·48	33·80	41·60		150·85	181·92	213·28

TABLE XIII.—WEIGHT OF SOLID DRAWN WROUGHT-IRON PIPES *per foot run; internal diameter.*

Internal diameter of pipe in inches.	Thickness of metal in parts of an inch.							
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
	Weight per foot run in pounds.							
$\frac{1}{4}$	·21	·50	·9	1·3	1·9	2·5	3·1	3·9
$\frac{3}{8}$	·30	·70	1·1	1·6	2·3	2·9	3·8	4·6
$\frac{1}{2}$	·40	·83	1·4	2·0	2·7	3·5	4·3	5·3
$\frac{5}{8}$	·46	1·1	1·6	2·3	3·1	3·9	4·9	5·9
$\frac{3}{4}$	·54	1·2	1·9	2·6	3·5	4·5	5·5	6·6
$\frac{7}{8}$	·60	1·3	2·1	2·9	3·9	4·9	6·1	7·3
1	·70	1·5	2·4	3·3	4·3	5·5	6·7	7·9
$1\frac{1}{4}$	·87	1·8	2·9	3·9	5·2	6·4	7·8	9·3
$1\frac{1}{2}$	1·00	2·1	3·3	4·7	5·9	7·4	8·9	10·6
$1\frac{3}{4}$	1·20	2·5	3·8	5·3	6·8	8·4	10·1	11·9
2	1·40	2·8	4·3	5·9	7·6	9·5	11·3	13·2
$2\frac{1}{4}$	1·53	3·1	4·8	6·6	8·5	10·4	12·4	14·5
$2\frac{1}{2}$	1·70	3·5	5·3	7·3	9·3	11·4	13·6	15·9
$2\frac{3}{4}$	1·90	3·8	5·8	7·9	10·1	12·4	14·7	17·2
3	2·03	4·1	6·3	8·6	10·9	13·3	15·9	18·5

TABLE XIV.—WEIGHT OF SOLID DRAWN WROUGHT-IRON PIPES *per foot run; external diameter.*

External diameter in inches.	Thickness in parts of an inch.		
	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$
	Weight per foot in pounds.		
2	2·47	3·58	4·61
$2\frac{1}{8}$	2·63	3·88	4·94
$2\frac{1}{4}$	2·79	4·07	5·27
$2\frac{3}{8}$	2·96	4·32	5·59
$2\frac{1}{2}$	3·14	4·57	5·92
$2\frac{5}{8}$	3·29	4·81	6·25
$2\frac{3}{4}$	3·46	5·06	6·58
$2\frac{7}{8}$	3·61	5·30	6·91
3	3·78	5·55	7·24
$3\frac{1}{8}$	3·95	5·80	7·57
$3\frac{1}{4}$	4·12	6·05	7·90

TABLE XV.—WEIGHT OF LARGE WELDED WROUGHT-IRON PIPES *per foot run.*

Internal diameter of pipe in inches.	Thickness in parts of an inch.			
	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
	Weight per foot in pounds.			
10	20	26	33	40
11	22	29	37	44
12	24	32	40	48
13	26	34	43	52
14	28	37	47	56
15	30	40	50	60
16	32	42	53	64
17	33	45	56	68
18	35	47	59	72
19	37	50	63	76
20	39	53	66	80
21	41	55	69	84
22	43	58	73	88
23	45	61	76	92
24	47	63	79	96

TABLE XVI.—WEIGHT OF RIVETED WROUGHT-IRON PIPES *per foot run.*

Internal diameter of pipe in inches.	Thickness of pipe in parts of an inch.				
	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
	Weight per foot in pounds.				
12	19	29	38	48	58
15	23	34	46	59	71
18	28	41	55	70	84
24	36	54	72	91	109
30	44	66	89	112	134
36	53	79	105	133	159
42	61	92	122	153	184
48	70	104	139	161	209

TABLE XVII.—WEIGHT OF ANGLE-IRON FLANGE RINGS FOR RIVETED IRON PIPES.

Bore of pipe in inches.	Size of angle-iron.			
	$2 \times 2 \times \frac{3}{8}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	$3 \times 3 \times \frac{1}{2}$	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$
	Weight of each ring in pounds.			
10	15	20	36	51
11	16	22	39	54
12	18	23	41	58
13	19	25	44	61
14	20	26	47	65
15	21	28	49	68
16	22	29	52	72
17	24	31	55	75
18	25	32	57	79
19	26	34	60	82
20	27	35	62	86
21	28	37	65	89
22	30	38	68	93
23	31	40	70	96
24	32	41	73	100

TABLE XVIII.—WEIGHT OF STEEL SOCKETS RIVETED ON PIPES.

Bore of pipe in inches.	Weight of socket in lbs.	Bore of pipe in inches.	Weight of socket in lbs.
10	10	18	25
11	11	19	29
12	12	20	32
13	13	21	34
14	14	22	35
15	16	23	37
16	19	24	38
17	22		

TABLE XIX.—WEIGHT OF SOLID-DRAWN COPPER TUBES *per foot run.*

Diameter of bore of tube inches.	Imperial wire gauge.												
	6	7	8	9	10	11	12	13	14	15	16	17	18
	Millimètres.												
	·192	·176	·160	·144	·128	·116	·104	·092	·080	·072	·064	·056	·048
	Weight per lineal foot in pounds.												
3/8	1·32	1·17	1·04	0·90	0·78	0·70	0·60	0·52	0·44	0·39	0·34	0·30	0·25
1/2	1·61	1·44	1·28	1·12	0·97	0·87	0·76	0·66	0·56	0·50	0·44	0·38	0·32
5/8	1·90	1·70	1·52	1·34	1·17	1·05	0·92	0·80	0·68	0·61	0·54	0·47	0·39
3/4	2·19	1·97	1·77	1·56	1·37	1·22	1·08	0·94	0·80	0·72	0·63	0·55	0·47
1	2·79	2·51	2·26	2·00	1·76	1·58	1·39	1·21	1·04	0·93	0·83	0·72	0·61
1¼	3·36	3·05	2·74	2·44	2·15	1·93	1·71	1·49	1·29	1·15	1·02	0·89	0·76
1½	3·98	3·60	3·23	2·88	2·54	2·28	2·03	1·77	1·53	1·37	1·22	1·06	0·91
1¾	4·53	4·12	3·72	3·31	2·93	2·63	2·34	2·05	1·77	1·59	1·41	1·23	1·05
2	5·11	4·66	4·20	3·75	3·32	2·99	2·66	2·33	2·02	1·81	1·61	1·40	1·20
2½	6·28	5·73	5·18	4·63	4·10	3·70	3·30	2·89	2·50	2·25	2·00	1·76	1·49
3	7·46	6·80	6·15	5·50	4·87	4·40	3·93	3·45	3·00	2·68	2·38	2·08	1·77
3½	8·62	7·87	7·12	6·39	5·66	5·11	4·56	4·01	3·48	3·12	2·77	2·41	2·06
4	9·78	8·94	8·10	7·26	6·43	5·81	5·20	4·57	3·97	3·56	3·17	2·75	2·35
4½	10·95	10·00	9·05	8·13	7·21	6·53	5·83	5·13	4·45	4·00	3·53	3·09	2·64
5	12·13	11·08	10·05	9·00	8·00	7·23	6·46	5·69	4·94	4·44	3·92	3·42	2·93
5½	13·30	12·16	11·02	9·90	8·78	7·94	7·10	6·25	5·43	4·85	4·31	3·76	3·22
6	14·50	13·25	12·00	10·75	9·56	8·66	7·74	6·81	5·91	5·29	4·69	4·10	3·51

TABLE XX.—WEIGHT OF LOOSE SOCKETS.
(Fig. 49.)

Bore of pipe in inches.	Weight of socket in lbs.	Bore of pipe in inches.	Weight of socket in lbs.	Bore of pipe in inches.	Weight of socket in lbs.
10	25	15	36	20	46
11	27	16	38	21	48
12	29	17	40	22	51
13	31	18	42	23	53
14	33	19	44	24	55

TABLE XXI.—THICKNESS OF STEEL STEAM PIPES FOR VARYING PRESSURES.

Diameter of bore of pipes in inches.	Steam pressure in lbs. per square inch.			
	100	120	150	180
	Hydraulic test pressure in lbs. per square inch.			
	200	240	300	360
	Thickness of pipe in inches.			
6	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
7	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
8	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
9	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$
10	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$
11	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$
12	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$
13	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$
14	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$
15	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$
16	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
17	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
18	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$

TABLE XXII.—WEIGHT OF COPPER TUBES *per foot run.*

Diameter of bore of tube. inches.	Thickness in parts of an inch.		
	⅛	3/16	¼
	Weight per foot run in lbs. and ounces.		
½	0 15	1 10¼	2 4¼
⅝	1 12½	1 14	2 10½
¾	1 15½	2 3	3 0½
⅞	1 8¼	2 7½	3 6½
1	1 11	2 11½	3 12½
1⅛	1 14¼	3 0	4 2
1¼	2 1¼	3 4¾	4 8
1⅜	2 3¾	3 8¾	4 14
1½	2 7	3 13½	5 4
1⅝	2 11	4 2½	5 10
1¾	2 14	4 7	6 0
1⅞	3 0½	4 11¼	6 6
2	3 3½	4 15¾	6 12
2⅛	3 6¼	5 4	7 2
2¼	3 9½	5 8½	7 8
2⅜	3 12	5 13¼	7 14
2½	3 15½	6 1¾	8 4
2⅝	4 2¼	6 6	8 10
2¾	4 5½	6 10¼	9 0
2⅞	4 9	6 15½	9 6
3	4 12½	7 4¼	9 12
3⅛	4 15	7 9	10 4

TABLE XXIII.—WEIGHT OF BRASS TUBES *per foot run.*
Thickness in B. W. Gauge.

External diameter in inches.	No. of B. W. G.				
	9	10	11	12	13
	Weight of pipe per foot run in pounds.				
1⅜	2·10	1·92	1·74	1·59	1·40
1½	2·32	2·11	1·92	1·75	1·54
1⅝	2·52	2·30	2·09	1·90	1·68
1¾	2·73	2·50	2·26	2·06	1·81
1⅞	2·95	2·69	2·44	2·22	1·95
2	3·17	2·89	2·61	2·37	2·08

TABLE XXIV.—WEIGHT OF BRASS TUBES *per foot run.* *Thickness in parts of an inch.*

Diameter of bore of tube in inches.	Thickness in parts of an inch.		
	⅛	3/16	¼
	Weight per foot run in lbs. and ounces.		
1	1 9½	2 4	3 8½
1⅛	1 12¼	2 8½	3 14½
1¼	1 15½	2 12¼	4 4
1⅜	2 2	3 0½	4 10
1½	2 5	3 4½	4 15½
1⅝	2 7½	3 8½	5 5
1¾	2 10½	3 12½	5 11
1⅞	2 13½	4 0½	6 0½
2	3 0	4 5	6 6½
2⅛	3 3	4 9¼	6 12
2¼	3 6	4 13¼	7 2
2⅜	3 9	5 1½	7 7¼
2½	3 11¾	5 6	7 12
2⅝	3 14½	5 10	8 2½
2¾	4 1½	5 14	8 8½
2⅞	4 4¼	6 2	8 14
3	4 7	6 6	9 4
3¼	4 12½	6 14½	9 15½
3½	5 2¼	7 6½	10 11
3¾	5 8	7 15	11 5¾
4	5 14	8 7½	12 1
5	7 4	10 8	14 14½
6	8 11	12 10	17 12

TABLE XXV.—WEIGHT OF LEAD PIPES *per length.*

Bore of pipe in inches.	Length of pipe in feet.	Weight of one length in pounds.					
		Common		Middling		Strong	
		Thickness in inches.	Weight in lbs.	Thickness in inches.	Weight in lbs.	Thickness in inches.	Weight in lbs.
½	15	0·2	16	0·29	22		26
¾	15		24		28		36
1	15	0·11	30	0·15	40	0·17	46
1¼	12		36		44		53
1½	12		48		56		70
2	10	0·17	56	0·21	70	0·34	83
2½	10		70		86		100

TABLE XXVI.—THICKNESS OF PIPES REQUIRED FOR DIFFERENT HEADS OF WATER IN FEET. STRESS ON METAL BEING TAKEN AT 2500 LBS. PER SQUARE INCH.

Head of Water in Feet.	Diameter of Pipes in Inches.																								
	2	2½	3	3½	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Thickness of Metal in Inches and Fractions of an Inch.																								
10	¼	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	¼	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	¼	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	¼	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
60	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
110	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
120	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
130	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
140	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
160	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
170	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
180	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
190	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
200	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
210	¼	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
220	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
230	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1
240	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1
250	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	[illegible]
260	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	[illegible]	[illegible]
270	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	[illegible]	[illegible]	[illegible]
280	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]
290	¼	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]
300	¼	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

310	¼	⅜	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	⅝	¾	¾	¾	⅞	⅞	1	1	1⅛	1⅛	1¼	1¼	1¼	1⅜
320	¼	⅜	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	⅝	¾	¾	⅞	⅞	1	1	1⅛	1⅛	1⅛	1¼	1¼	1⅜	1⅜
330	¼	⅜	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	¾	¾	¾	⅞	⅞	1	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1⅜
340	¼	⅜	⅜	⅜	⅜	⅜	⅜	½	½	⅝	⅝	¾	¾	¾	⅞	1	1	1⅛	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½
350	¼	⅜	⅜	⅜	⅜	⅜	⅜	½	½	⅝	⅝	¾	¾	⅞	⅞	1	1	1⅛	1⅛	1⅛	1¼	1⅜	1⅜	1½	1½
360	¼	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	⅝	¾	⅞	⅞	1	1	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½	1½
370	¼	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	⅝	¾	⅞	⅞	1	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½	1½	1⅝
380	¼	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	⅝	¾	⅞	⅞	1	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½	1⅝	1⅝
390	¼	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	⅝	¾	⅞	1	1	1	1⅛	1¼	1¼	1⅜	1⅜	1½	1½	1⅝	1⅝
400	¼	⅜	⅜	⅜	⅜	⅜	½	½	½	⅝	¾	¾	⅞	1	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½	1⅝	1⅝	1¾
410	¼	⅜	⅜	⅜	⅜	⅜	½	½	⅝	⅝	¾	⅞	⅞	1	1	1⅛	1¼	1¼	1¼	1⅜	1½	1½	1⅝	1¾	1¾
420	¼	⅜	⅜	⅜	⅜	⅜	½	½	⅝	¾	¾	⅞	⅞	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½	1⅝	1⅝	1¾	1¾
430	¼	⅜	⅜	⅜	⅜	⅜	½	⅝	⅝	¾	¾	⅞	1	1	1⅛	1⅛	1¼	1¼	1⅜	1½	1½	1⅝	1¾	1¾	1⅞
440	¼	⅜	⅜	⅜	⅜	½	½	⅝	⅝	¾	¾	⅞	1	1	1⅛	1¼	1¼	1⅜	1⅜	1½	1⅝	1⅝	1¾	1⅞	1⅞
450	¼	⅜	⅜	⅜	⅜	½	½	⅝	⅝	¾	¾	⅞	1	1⅛	1⅛	1¼	1¼	1⅜	1⅜	1½	1⅝	1⅝	1¾	1⅞	1⅞
460	¼	⅜	⅜	⅜	⅜	½	½	⅝	¾	¾	⅞	⅞	1	1⅛	1⅛	1¼	1⅜	1⅜	1⅜	1⅝	1⅝	1¾	1¾	1⅞	2
470	¼	⅜	⅜	⅜	⅜	½	½	⅝	¾	¾	⅞	⅞	1	1⅛	1¼	1¼	1⅜	1½	1½	1⅝	1¾	1¾	1⅞	1⅞	2
480	¼	⅜	⅜	⅜	⅜	½	½	⅝	¾	¾	⅞	1	1	1⅛	1¼	1⅜	1⅜	1½	1½	1⅝	1¾	1¾	1⅞	1⅞	2
490	¼	⅜	⅜	⅜	⅜	½	⅝	⅝	¾	¾	⅞	1	1⅛	1¼	1¼	1⅜	1⅜	1½	1½	1⅝	1¾	1⅞	1⅞	2	2⅛
500	¼	⅜	⅜	⅜	⅜	½	⅝	⅝	¾	⅞	⅞	1	1⅛	1¼	1¼	1⅜	1½	1½	1⅝	1¾	1¾	1⅞	2	2	2⅛
510	¼	⅜	⅜	⅜	⅜	½	⅝	⅝	¾	⅞	1	1	1⅛	1¼	1¼	1⅜	1½	1⅝	1⅝	1¾	1⅞	1⅞	2	2⅛	2⅛
520	¼	⅜	⅜	⅜	⅜	½	⅝	⅝	¾	⅞	1	1	1⅛	1⅜	1⅜	1⅜	1½	1⅝	1⅝	1¾	1⅞	2	2	2⅛	2¼
530	¼	⅜	⅜	⅜	⅜	½	⅝	⅝	¾	⅞	1	1⅛	1⅛	1⅜	1⅜	1½	1½	1⅝	1⅝	1¾	1⅞	2	2	2⅛	2¼
540	¼	⅜	⅜	⅜	½	½	⅝	¾	¾	⅞	1	1⅛	1⅛	1⅜	1⅜	1½	1½	1⅝	1¾	1⅞	1⅞	2	2⅛	2¼	2¼
550	¼	⅜	⅜	⅜	½	½	⅝	¾	⅞	⅞	1	1⅛	1¼	1⅜	1⅜	1½	1⅝	1⅝	1¾	1⅞	2	2	2⅛	2¼	2⅜
560	¼	⅜	⅜	⅜	½	½	⅝	¾	⅞	⅞	1	1⅛	1¼	1⅜	1⅜	1½	1⅝	1¾	1¾	1⅞	2	2⅛	2⅛	2¼	2⅜
570	¼	⅜	⅜	⅜	½	½	⅝	¾	⅞	1	1	1⅛	1¼	1½	1½	1½	1⅝	1¾	1¾	1⅞	2	2⅛	2¼	2⅜	2⅜
580	¼	⅜	⅜	⅜	½	½	⅝	¾	⅞	1	1⅛	1¼	1¼	1½	1½	1⅝	1⅝	1¾	1⅞	2	2⅛	2⅛	2¼	2⅜	2½
590	¼	⅜	⅜	⅜	½	⅝	⅝	¾	⅞	1	1⅛	1¼	1¼	1½	1½	1⅝	1¾	1¾	1⅞	2	2⅛	2¼	2¼	2⅜	2½
600	¼	⅜	⅜	⅜	½	⅝	⅝	¾	⅞	1	1⅛	1¼	1¼	1½	1½	1⅝	1¾	1⅞	1⅞	2	2⅛	2¼	2⅜	2½	2½
610	¼	⅜	⅜	⅜	½	⅝	¾	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1⅝	1¾	1⅞	1⅞	2⅛	2⅛	2¼	2⅜	2½	2⅝
620	¼	⅜	⅜	⅜	½	⅝	¾	⅞	⅞	1	1⅛	1¼	1⅜	1⅝	1⅝	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2⅜	2½	2⅝
630	¼	⅜	⅜	⅜	½	⅝	¾	⅞	⅞	1	1¼	1¼	1⅜	1⅝	1⅝	1¾	1⅞	1⅞	2	2⅛	2¼	2⅜	2⅜	2⅝	2⅝
640	¼	⅜	⅜	⅜	½	⅝	¾	⅞	1	1	1¼	1⅜	1⅜	1⅝	1⅝	1¾	1⅞	2	2	2⅛	2¼	2⅜	2½	2⅝	2¾
650	¼	⅜	⅜	½	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1⅜	1⅝	1⅝	1¾	1⅞	2	2⅛	2¼	2¼	2⅜	2½	2⅝	2¾
660	¼	⅜	⅜	½	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2½	2¾	2¾
670	¼	⅜	⅜	½	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞
680	¼	⅜	⅜	½	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞
690	¼	⅜	⅜	½	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2¾	2⅞

TABLE XXVI (*Continued*).

Head of Water in Feet.	Diameter of Pipes in Inches.																							
	2	2½	3	3½	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Thickness of Metal in Inches and Fractions of an Inch.																								
700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	¾	⅞	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1¾	1⅞	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3
710	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	¾	⅞	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1¾	1⅞	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3
720	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	¾	⅞	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1¾	1⅞	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3
730	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1⅛	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2⅛	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3⅛
740	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]
750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3	3 [illegible]
760	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3⅛	3 [illegible]
770	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1⅞	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]
780	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2⅛	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3	3 [illegible]	3 [illegible]
790	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3⅛	3 [illegible]	3 [illegible]
800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]
810	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]
820	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3	3 [illegible]	3 [illegible]	3 [illegible]
830	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1⅛	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2⅛	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3⅛	3 [illegible]	3 [illegible]	3 [illegible]
840	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	⅞	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1⅞	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
850	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
860	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
870	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3⅛	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
880	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
890	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2⅛	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1⅞	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
910	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
920	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3⅛	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]
930	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3⅞
940	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	4
950	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1⅛	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	4
960	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	4
970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2⅛	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3⅛	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	4⅛
980	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1⅞	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2⅞	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	4 [illegible]
990	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3⅞	4 [illegible]
1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	1 [illegible]	2	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	2 [illegible]	3	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	3 [illegible]	4	4 [illegible]

TABLE XXVII.—WEIGHT OF LEAD PIPE REQUIRED FOR A GIVEN HEAD OF WATER.

Head of fall in feet.	Pressure in lbs. per square inch.	Diameter of pipe in inches.						
		3/8	1/2	5/8	3/4	1	1¼	1½
		Weight per foot of pipe in pounds.						
20	10	0·38	0·63	0·87	1·00	1·5	2·0	3·0
30	15	0·50	0·75	1·38	1·50	2·0	2·5	3·5
40	20	0·68	1·00	1·75	2·0	2·5	3·0	4·0
50	25	0·75	1·25	2·0	2·5	3·0	4·0	5·0
75	38	1·00	1·63	2·38	3·38	4·0	5·0	6·0
100	50	1·25	2·0	3·00	4·0	5·0	7·0	10·0
150	75	1·38	2·5	3·5	4·5	6·0	9·0	12·0
200	100	1·5	3·0	4·0	5·0	7·0	12·0	15·0

TABLE XXVIII.—WEIGHT OF LEAD PIPES PER LINEAL FOOT.

Diameter of pipe in inches.	Thickness of pipe in fractions of an inch.							
	1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4
	Weight per lineal foot in pounds.							
3/8	·427	·97	1·65	2·44	4·38			
1/2	·548	1·21	2·01	2·93	5·11	7·79		
5/8	·670	1·46	2·38	3·42	5·85	8·77	12·0	
3/4	·791	1·70	2·74	3·90	6·58	9·75	13·4	17·6
7/8	·911	1·95	3·11	4·59	7·31	10·7	14·6	19·1
1	1·03	2·19	3·47	4·88	8·04	11·7	15·8	20·5
1¼	1·28	2·69	4·21	5·85	9·50	13·7	18·3	23·4
1½	1·52	3·18	4·94	6·83	11·0	15·6	20·7	26·3
1¾	1·76	3·67	5·67	7·31	12·4	17·6	23·2	29·3
2	2·01	4·16	6·40	8·78	13·9	19·5	25·6	32·3
2¼	2·25	4·65	7·13	9·76	15·4	21·5	28·1	35·1
2½	2·49	5·14	7·86	10·7	16·8	23·4	30·5	38·0
2¾	2·73	5·63	8·59	11·7	18·3	25·4	32·9	41·0
3	2·98	6·12	9·32	12·7	19·7	27·3	35·4	43·9
3½	3·46	7·10	10·8	14·6	22·7	31·3	40·3	49·7
4	3·95	8·08	12·2	16·6	25·6	35·2	45·2	55·6

TABLE XXIX.—WEIGHT OF LEAD PIPES, AND PATENT COMPOSITION GAS PIPES.

Internal diameter in inches.	Weight of pipes per yard.	Average length in yards.
¼	12 oz.	75
⅜	19 oz.	56
½	2 lbs.	28
⅝	3 lbs.	19
¾	4 lbs.	14
1	5½ lbs.	10
1¼	9 lbs.	13
1½	11 lbs.	10

TABLE XXX.—BURSTING PRESSURE AND TENSILE STRENGTH OF EARTHENWARE PIPES.

Name of maker.	Where made.	Size of pipe in inches.	Thickness of pipe in inches.	Bursting pressure in lbs. per square inch.	Tensile strength in lbs. per square inch.	Length of pipe.	
						feet.	ins.
Doulton & Co.	Staffordshire	6	0·65	50	230·7	1	11
Doulton & Co.	London	6	0·72	10	41·6	1	11
Ingham & Co.	Wortley	6	0·48	4	25·0	1	11
Ingham & Co.	Wortley	6	0·69	70	304·3	1	11
S. Fisher	London	6	0·57	15	78·9	2	0
T. H. Seacombe	Ruabon	6	0·70	5	21·4	1	10½
T. H. Seacombe	North Wales	6	0·70	5	21·4	1	10½
Aylesford	Aylesford	9	1·00	45	202·5	2	0
Doulton & Co.	London	9	0·84	40	214·5	2	0
Doulton & Co.	Staffordshire	9	0·79	20	113·9	1	11
Cliff	Wortley	9	0·84	60	321·4	2	4
Brookes	Huddersfield	9	0·91	55	271·9	2	6
T. H. Seacombe	Ruabon	9	0·94	30	143·6	1	11
T. H. Seacombe	North Wales	9	0·94	30	143·6	1	11
Doulton & Co.	Staffordshire	12	1·07	7	39·2	2	0
Wilcox & Co.	Wortley	12	0·94	7	44·6	1	11
Stiff & Son	London	14	0·95	30	221·0	1	10
Doulton & Co.	Staffordshire	15	1·10	20	136·3	1	10
Doulton & Co.	London	15	1·19	33	207·9	2	5

Table XXXI.—Experiments on the Crushing of Earthenware Pipes.

Conducted at the works of Burton and Waller.

Date of experiment.	Maker's name.	Diameter of pipe in inches.	Thickness of pipe in inches.	Weight of pipe in lbs.	Breaking weight in lbs.	Number of pieces of broken pipe.	Remarks.
July 18, 1855	Doulton	8⅝ × 8⅞	0·75		2713		Without felt pad.
,, ,, ,,	Doulton	8⅝ × 8⅞	0·75		2470		With felt pad.
,, ,, ,,	Aylesbury pipe	8⅝ × 8¾	1·00		2106		Without felt pad.
,, ,, ,,	Aylesbury pipe	8⅝ × 8¾	1·00		2106		
,, ,, ,,	Aylesbury pipe	8⅞ × 8⅞	1·00		3077		With felt pad.
,, ,, ,,	Stiff	8⅝ × 9	0·812		2106		Without felt pad.
,, ,, ,,	Stiff	8⅝ × 9	0·812		2228		With felt pad.
,, ,, ,,	Doulton	11½ × 11¾	1·00		3684		Pipe placed with large diameter vertical.
,, ,, ,,	Doulton	11½ × 11¾	1·00		3684		
,, ,, ,,	Aylesford	12¼ × 12¼	1·125		2936		Felt pad round pipe.
,, ,, ,,	Aylesford	12¼ × 12¼	1·125		2470		
,, ,, ,,	Stiff	11¾ × 12	1·00		2834		
,, ,, ,,	Stiff	11⅞ × 12	0·937		2713		
May 2, 1856	Boucher	6	0·75	33·5	2956		Pipe hard and well burnt.
,, ,, ,,	Pilton	6	0·75	33·0	1864		Aylesford pipe not of true action, rather oval.
,, ,, ,,	Boucher	9	0·875	63·0	2228		
,, ,, ,,	Pilton	9	1·06	66·0	2775		Aylesford pipe.
,, ,, ,,	Boucher	12	0·935	91·0	2410		
,, ,, ,,	Pilton	12	1·125	94·0	2228		
May 15, 1856	Doulton	6	0·75	35·0	2713	5	Transverse fracture.
,, ,, ,,	Doulton	6	0·75	35·0	2531	6	
,, ,, ,,	Pilton	6	0·75	33·5	1803	5	Longitudinal fracture in nearly parallel pieces.
,, ,, ,,	Pilton	6	0·75	32·5	1742	5	
,, ,, ,,	Pilton	6	0·75	32·74	1864	6	
,, ,, ,,	Doulton	9	0·937	64·5	3561	9	Pipe well made and burnt.
,, ,, ,,	Doulton	9	0·937	62·0	2956	6	
,, ,, ,,	Pilton	9	1·00	62·5	2470	6	
,, ,, ,,	Pilton	9	1·00	63·5	2470	5	
,, ,, ,,	Pilton	9	1·00	64·0	2228	6	Badly burnt.
,, ,, ,,	Doulton	12	0·99	93·5	2834	9	These pipes had a fillet on spigot end.
,, ,, ,,	Doulton	12	0·937	92·0	2956	7	
,, ,, ,,	Pilton	12	1·125	95·5	2470	7	Aylesford pipe, irregular in section and inferior in quality.
,, ,, ,,	Pilton	12	1·125	98·25	2350	5	
,, ,, ,,	Pilton	12	1·187	90·5	2228	7	

TABLE XXXII.—STONEWARE AND FIRE-CLAY PIPES.

Stoneware pipes.				Fire-clay pipes.			
Internal diameter in inches.	Thickness in inches.	Length in work in feet.	Depth of socket in inches.	Internal diameter in inches.	Thickness in inches.	Length in work in feet.	Depth of socket in inches.
3	⅜	2	1½	3	⅜	2	1½
4	½	2	1½	4	½	2	1½
6	⅝	2	1¾	6	¾	2	1¾
9	¾	2	2	9	⅘	2	2
10	⅞	2	2	10	1	2	2
12	1	2	2	12	1⅒	2	2
15	1⅛	2	2¼	15	1¼	2 to 3	2¼
18	1¼	2 to 3	2½	18	1½	2 to 3	2½

TABLE XXXIII.—SQUARE OF NUMBERS.

Number. N	Square. N^2	Number. N	Square. N^2	Number. N	Square. N^2
⅛	0·015625	2¼	5·062500	5½	30·2500
¼	0·062500	2⅜	5·640625	5¾	33·0625
⅜	0·140625	2½	6·250000		
½	0·250000	2⅝	6·890625	6	36·0000
⅝	0·390625	2¾	7·562500	6¼	39·0625
¾	0·562500	2⅞	8·265625	6½	42·2500
⅞	0·765625			6¾	45·5625
		3	9·000000		
1	1·000000	3¼	10·56250	7	49·0000
1⅛	1·265626	3½	12·25000	7¼	52·5625
1¼	1·562500	3¾	14·06250	7½	56·2500
1⅜	1·890625			7¾	60·0625
1½	2·250000	4	16·00000		
1⅝	2·640625	4¼	18·06250	8	64·0000
1¾	3·062500	4½	20·2500	8¼	68·0625
1⅞	3·515625	4¾	22·5625	8½	72·2500
				8¾	76·5625
2	4·000000	5	25·0000		
2⅛	4·515625	5¼	27·5625	9	81·0000

TABLE XXXIII (*Continued*).

Number. N	Square. N^2	Number. N	Square. N^2	Number. N	Square. N^2
9¼	85·5625	17	289·000	31½	992·25
9½	90·2500	17¼	297·562	32	1024·00
9¾	95·0625	17½	306·250	32½	1056·25
		17¾	315·062	33	1089·00
10	100·000			33½	1122·25
10¼	105·062	18	324·000	34	1156·00
10½	110·250	18¼	337·062	34½	1190·25
10¾	113·562	18½	342·250	35	1225·00
		18¾	351·562	35½	1260·25
11	121·000			36	1296·00
11¼	126·562	19	361·000	36½	1332·25
11½	132·250	19¼	370·562	37	1369·00
11¾	138·062	19½	380·250	37½	1406·25
		19¾	390·062	38	1444·00
12	144·000			38½	1482·25
12¼	150·062	20	400·00	39	1521·00
12½	156·250	20½	420·25	39½	1560·25
12¾	162·562	21	441·00		
		21½	462·25	40	1600·00
13	169·000	22	484·00	40½	1640·25
13¼	175·562	22½	506·25	41	1681·00
13½	182·250	23	529·00	41½	1722·25
13¾	189·062	23½	552·25	42	1764·00
		24	576·00	42½	1806·25
14	196·000	24½	600·25	43	1849·00
14¼	203·062	25	625·00	43½	1892·25
14½	210·250	25½	650·25	44	1936·00
14¾	217·562	26	676·00	44½	1980·25
		26½	702·25	45	2025·00
15	225·000	27	729·00	45½	2070·25
15¼	232·562	27½	756·25	46	2116·00
15½	240·250	28	784·00	46½	2162·25
15¾	248·062	28½	812·25	47	2209·00
		29	841·00	47½	2256·25
16	256·000	29½	870·25	48	2304·00
16¼	264·062			48½	2352·25
16½	272·250	30	900·00	49	2401·00
16¾	280·562	30½	930·25	49½	2450·25
		31	961·00		

TABLE XXXIII (*Continued*).

Number. N	Square. N^2	Number. N	Square. N^2	Number. N	Square. N^2
50	2500·00	67½	4556·25	84½	7140·25
50½	2550·25	68	4624·00	85	7205·00
51	2601·00	68½	4692·25	85½	7310·25
51½	2652·25	69	4761·00	86	7396·00
52	2704·00	69½	4830·25	86½	7482·25
52½	2756·25			87	7569·00
53	2809·00	70	4900·00	87½	7656·25
53½	2862·25	70½	4970·25	88	7744·00
54	2916·00	71	5041·00	88½	7832·25
54½	2970·25	71½	5112·25	89	7921·00
55	3025·00	72	5184·00	89½	8010·25
55½	3080·25	72½	5256·25		
56	3136·00	73	5329·00	90	8100·00
56½	3192·25	73½	5402·25	90½	8190·25
57	3249·00	74	5476·00	91	8281·00
57½	3306·25	74½	5550·25	91½	8372·25
58	3364·00	75	5625·00	92	8464·00
58½	3422·25	75½	5700·25	92½	8556·25
59	3481·00	76	5776·00	93	8649·00
59½	3540·25	76½	5852·25	93½	8742·25
		77	5929·00	94	8836·00
60	3600·00	77½	6006·25	94½	8930·25
60½	3660·25	78	6084·00	95	9025·00
61	3721·00	78½	6162·25	95½	9120·25
61½	3782·25	79	6241·00	96	9216·00
62	3844·00	79½	6330·25	96½	9322·25
62½	3906·25			97	9409·00
63	3969·00	80	6400·00	97½	9506·25
63½	4032·25	80½	6480·25	98	9604·00
64	4096·00	81	6561·00	98½	9702·25
64½	4160·25	81½	6642·25	99	9801·00
65	4225·00	82	6724·00	99½	9900·25
65½	4290·25	82½	6806·25		
66	4356·00	83	6889·00	100	10000
66½	4422·25	83½	6972·25	101	10201
67	4489·00	84	7056·00	102	10404

TABLE XXXIV.—SQUARE ROOT OF NUMBERS.

Number. N	Square Root. $\sqrt{N}$	Number. N	Square Root. $\sqrt{N}$	Number. N	Square Root. $\sqrt{N}$
1	1·0000	19	4·3589	36½	6·0414
1½	1·2071	19½	4·4155	37	6·0828
2	1·4142			37½	6·1236
2½	1·5731	20	4·4721	38	6·1644
3	1·7321	20½	4·5274	38½	6·2047
3½	1·8660	21	4·5826	39	6·2450
4	2·0000	21½	4·6365	39½	6·2848
4½	2·1180	22	4·6904		
5	2·2361	22½	4·7431	40	6·3246
5½	2·3428	23	4·7958	40½	6·3638
6	2·4495	23½	4·8474	41	6·4031
6½	2·5476	24	4·8990	41½	6·4419
7	2·6458	24½	4·9495	42	6·4807
7½	2·7371	25	5·0000	42½	6·5191
8	2·8284	25½	5·0495	43	6·5574
8½	2·9142	26	5·0990	43½	6·5953
9	3·0000	26½	5·1476	44	6·6332
9½	3·0811	27	5·1962	44½	6·6707
		27½	5·2438	45	6·7082
10	3·1632	28	5·2915	45½	6·7453
10½	3·2395	28½	5·3383	46	6·7823
11	3·3166	29	5·3852	46½	6·8189
11½	3·3904	29½	5·4312	47	6·8557
12	3·4641			47½	6·8919
12½	3·5348	30	5·4772	48	6·9282
13	3·6056	30½	5·5224	48½	6·9641
13½	3·6736	31	5·5678	49	7·0000
14	3·7414	31½	5·6123	49½	7·0355
14½	3·8073	32	5·6569		
15	3·8730	32½	5·7007	50	7·0711
15½	3·9365	33	5·7446	50½	7·1063
16	4·0000	33½	5·7878	51	7·1414
16½	4·0616	34	5·8310	51½	7·1763
17	4·1231	34½	5·8735	52	7·2111
17½	4·1829	35	5·9161	52½	7·2456
18	4·2426	35½	5·9580	53	7·2801
18½	4·3008	36	6·0000	53½	7·3143

Table XXXIV (*Continued*).

Number. N	Square Root. $\sqrt{N}$	Number. N	Square Root. $\sqrt{N}$	Number. N	Square Root. $\sqrt{N}$
54	7·3485	69½	8·3366	84½	9·1924
54½	7·3823			85	9·2195
55	7·4162	70	8·3666	85½	9·2466
55½	7·4498	70½	8·3964	86	9·2736
56	7·4833	71	8·4261	86½	9·3005
56½	7·5166	71½	8·4557	87	9·3274
57	7·5498	72	8·4853	87½	9·3541
57½	7·5828	72½	8·5146	88	9·3808
58	7·6158	73	8·5440	88½	9·4074
58½	7·6485	73½	8·5732	89	9·4340
59	7·6811	74	8·6023	89½	9·4604
59½	7·7136	74½	8·6313	90	9·4868
		75	8·6603	90½	9·5131
60	7·7460	75½	8·6890	91	9·5394
60½	7·7781	76	8·7178	91½	9·5655
61	7·8102	76½	8·7464	92	9·5917
61½	7·8421	77	8·7750	92½	9·6177
62	7·8740	77½	8·8034	93	9·6437
62½	7·9056	78	8·8318	93½	9·6695
63	7·9373	78½	8·8600	94	9·6954
63½	7·9686	79	8·8882	94½	9·7211
64	8·0000	79½	8·9162	95	9·7468
64½	8·0311			95½	9·7724
65	8·0623	80	8·9443	96	9·7980
65½	8·0932	80½	8·9722	96½	9·8234
66	8·1240	81	9·0000	97	9·8489
66½	8·1547	81½	9·0279	97½	9·8742
67	8·1854	82	9·0554	98	9·8995
67½	8·2158	82½	9·0829	98½	9·9247
68	8·2462	83	9·1104	99	9·9499
68½	8·2764	83½	9·1378		
69	8·3066	84	9·1652	100	10·0000

TABLE XXXV.—FIFTH POWER OF NUMBERS.

Number. N	Fifth Power. N^5
⅛	0·000031
¼	0·000977
⅜	0·007416
½	0·031250
⅝	0·095367
¾	0·237305
⅞	0·512909
1	1·000000
1⅛	1·802032
1¼	3·051758
1⅜	4·914886
1½	7·593750
1⅝	11·33096
1¾	16·41308
1⅞	23·17428
2	32·00000
2⅛	43·33059
2¼	57·66504
2⅜	75·56454
2½	97·65625
2⅝	124·6369
2¾	154·2764
2⅞	194·4216
3	243·0000
3¼	362·5908
3½	525·2187
3¾	741·5771
4	1024·000
4¼	1386·579
4½	1845·281
4¾	2418·065
5	3125·000
5¼	3988·379
5½	5032·843
5¾	6285·491
6	7776·000
6¼	9536·743
6½	11602·906
6¾	14012·604
7	16807·000
7¼	20030·418
7½	23750·468
7¾	27958·155
8	32768·000
8¼	38218·157
8½	44370·531
8¾	51290·894
9	59049·000
9¼	67718·708
9½	77378·094
9¾	88109·669
10	100000·000
10¼	113140·821
10½	127628·156
10¾	143562·933
11	161051·000
11¼	180203·247
11½	201135·719
11¾	223969·733
12	248832·000
12¼	275854·735
12½	305175·781
12¾	336938·722
13	371293·000
13¼	408374·036
13½	448403·344
13¾	491488·647
14	537824·000
14¼	587589·899
14½	640973·406
14¾	698168·261
15	759375·000
15¼	824801·075
15½	894660·969
15¾	969176·312
16	1048576·000
16¼	1133096·313
16½	1222981·031
16¾	1318481·549
17	1419857·000
17¼	1527374·364
17½	1641308·593
17¾	1761942·726
18	1889568·000
18¼	2048797·540
18½	2177950·656
18¾	2317428·589
19	2476099·000
19¼	2643343·903
19½	2819506·219
19¾	3004937·889
20	3200000·000
20½	3720506·281
21	4084101·000

TABLE XXXV (*Continued*).

Number. N	Fifth Power. N^5	Number. N	Fifth Power. N^5	Number. N	Fifth Power. N^5
21½	4594013·844	31½	31013641·97	41½	123095020·1
22	5153632·000	32	33554432·00	42	130691232·0
22½	5766503·906	32½	36259082·03	42½	138657910·2
23	6436343·000	33	39135393·00	43	147008443·0
23½	7167031·469	33½	42191409·59	43½	155756537·7
24	7962624·000	34	45435424·00	44	164916224·0
24½	8827351·531	34½	48875979·66	44½	174501857·8
25	9765625·000	35	52521875·00	45	184528125·0
25½	10782039·09	35½	56417677·22	45½	195010045·3
26	11881376·00	36	60466176·00	46	205962976·0
26½	13068609·16	36½	64783487·28	46½	217402615·4
27	14348907·00	37	69343957·00	47	229345007·0
27½	15727636·72	37½	74157714·84	47½	241806542·9
28	17210368·00	38	79235168·00	48	254803968·0
28½	18802876·78	38½	84587004·91	48½	268354383·0
29	20511149·00	39	90224199·00	49	282475249·0
29½	22341384·34	39½	96158012·47	49½	297184390·6
30	24300000·00	40	102400000·0	50	312500000·0
30½	26393637·41	40½	108962012·5	50½	328440640·7
31	28629151·00	41	115856201·0	51	345025251·0

TABLE XXXVI.—FIFTH ROOT OF NUMBERS.

Number. N	Fifth Root. $\sqrt[5]{N}$	Number. N	Fifth Root. $\sqrt[5]{N}$	Number. N	Fifth Root. $\sqrt[5]{N}$
1	1·000	35	2·036	70	2·339
2	1·149	36	2·047	71	2·345
3	1·246	37	2·059	72	2·352
4	1·319	38	2·070	73	2·358
5	1·379	39	2·081	74	2·364
6	1·431			75	2·371
7	1·476	40	2·091	76	2·378
8	1·516	41	2·101	77	2·384
9	1·552	42	2·112	78	2·390
		43	2·122	79	2·396
10	1·585	44	2·132		
11	1·615	45	2·141	80	2·402
12	1·644	46	2·150	81	2·408
13	1·670	47	2·160	82	2·414
14	1·695	48	2·169	83	2·419
15	1·719	49	2·178	84	2·425
16	1·741	50	2·187	85	2·432
17	1·762	51	2·196	86	2·437
18	1·782	52	2·204	87	2·443
19	1·802	53	2·212	88	2·448
		54	2·221	89	2·454
20	1·821	55	2·229		
21	1·838	56	2·237	90	2·460
22	1·856	57	2·245	91	2·465
23	1·872	58	2·253	92	2·470
24	1·888	59	2·260	93	2·476
25	1·904			94	2·480
26	1·919	60	2·268	95	2·486
27	1·933	61	2·276	96	2·491
28	1·947	62	2·283	97	2·497
29	1·961	63	2·290	98	2·501
		64	2·297	99	2·507
30	1·974	65	2·304		
31	1·987	66	2·312	100	2·512
32	2·002	67	2·318	101	2·518
33	2·012	68	2·326	102	2·522
34	2·024	69	2·332	103	2·526

TABLE XXXVI (*Continued*).

Number. N	Fifth Root. $\sqrt[5]{N}$	Number. N	Fifth Root. $\sqrt[5]{N}$	Number. N	Fifth Root. $\sqrt[5]{N}$
104	2·531	119	2·601	134	2·663
105	2·536	120	2·605	135	2·667
106	2·541	121	2·609	136	2·672
107	2·546	122	2·613	137	2·676
108	2·551	123	2·618	138	2·678
109	2·555	124	2·622	139	2·682
		125	2·626		
110	2·560	126	2·630	140	2·686
111	2·565	127	2·634	141	2·691
112	2·569	128	2·639	142	2·695
113	2·574	129	2·643	143	2·698
114	2·578			144	2·702
115	2·583	130	2·646	145	2·706
116	2·587	131	2·651	146	2·710
117	2·592	132	2·656		
118	2·596	133	2·659		

TABLE XXXVII.—SQUARE ROOT OF THE FIFTH POWERS.

Number. N	$\sqrt{N^5}$	Number. N	$\sqrt{N^5}$	Number. N	$\sqrt{N^5}$	Number. N	$\sqrt{N^5}$
¼	0·031	8	181·02	23½	2677·1	43	12125
½	0·177	8¼	195·50	24	2821·8	44	12842
¾	0·485	8½	210·64	24½	2971·1	45	13584
		8¾	226·48	25	3125·0	46	14351
1	1·			25½	3283·6	47	15144
1¼	1·747	9	243·00	26	3446·9	48	15963
1½	2·756	9¼	260·23	26½	3615·1	49	16807
1¾	4·051	9½	278·17	27	3788·0		
		9¾	296·83	27½	3965·8	50	17678
2	5·657			28	4148·5	51	18575
2¼	7·594	10	316·23	28½	4336·2	52	19499
2½	9·882	10½	357·20	29	4528·9	53	20450
2¾	12·541	11	401·3	29½	4726·7	54	21428
		11½	448·5			55	22434
3	15·588	12	498·8	30	4929·5	56	23468
3¼	19·042	12½	552·4	30½	5138·0	57	24529
3½	22·918	13	609·3	31	5351·0	58	25620
3¾	27·232	13½	669·6	31½	5569·0	59	26738
		14	733·4	32	5793·0	60	27886
4	32·00	14½	800·6	32½	6022·0	61	29062
4¼	37·24	15	871·4	33	6256·0	62	30268
4½	42·96	15½	945·9	33½	6496·0	63	31503
4¾	49·17	16	1024·0	34	6741·0	64	32768
		16½	1105·9	34½	6991·0	65	34063
5	55·90	17	1191·6	35	7247·0	66	35388
5¼	63·15	17½	1281·1	35½	7509·0	67	36744
5½	70·94	18	1374·6	36	7776·0	68	38131
5¾	79·28	18½	1472·1	36½	8049·0	69	39548
		19	1573·6	37	8327·0		
6	88·18	19½	1679·1	37½	8611·0	70	40996
6¼	97·66			38	8901·0	71	42476
6½	107·72	20	1788·9	38½	9197·0	72	43988
6¾	118·38	20½	1902·8	39	9498·0	73	45531
		21	2020·9	39½	9806·0	74	47106
7	129·64	21½	2143·4			75	48714
7¼	141·53	22	2270·2	40	10119	76	50354
7½	154·05	22½	2401·4	41	10764	77	52027
7¾	167·21	23	2537·0	42	11432	78	53732

TABLE XXXVII (*Continued*).

Number. N	$\sqrt{N^5}$	Number. N	$\sqrt{N^5}$	Number. N	$\sqrt{N^5}$	Number. N	$\sqrt{N^5}$
79	55471	84	64669	90	76843	96	90298
		85	66611	91	78996	97	92668
80	57243	86	68588	92	81184	98	95075
81	59049	87	70509	93	83408	99	97519
82	60888	88	72645	94	85668		
83	62762	89	74727	95	87965	100	100000

INDEX

"Acme" joint, Lewis' patent, 80
Aird's patent flange tube, 78
Air pipes, 12
  ,, ,, head due to friction in, 13
  ,, ,, velocity of air in pipes, 12
  ,, quantity to be heated in rooms, 14
Albion Clay Company, taper pipe, 125
"Albion" pipe joint, 105
American pipe scraping machine, 150
Ames and Crosta's patent self-adjusting joint, 116
Angle-iron rings riveted to pipes, table of, 213
Angus Smith's process, 137
Appold's pipe scraping machine, 142
  ,, stone remover, 150
Armstrong's hydraulic flange joint, 37
Approximate weight of cast-iron pipes, rule for, 50

Balanced expansion joint, 170
Ball-and-socket joint, cast-iron, 40
  ,, ,, ,, ,, wrought-iron, 82
Bends, head of water due to friction in, 8
Bethlehem water-works, 17
Botham's earthenware pipe joint, 102
Bournemouth drain pipe, 81
Box-flanged pipe coupling—Howell and Littler's patent, 73
Bradford water-works steel pipes, 59
Brass pipes, 51
  ,, ,, rule for weight of, 89
  ,, ,, table of weight of, 216
  ,, tubes, table of weight of, 216
Brierly and Melling's lead pipe joint, 96
Brighton and Venning's patent drain pipe, 137
Brown and Company, balanced expansion joint, 170
Bursting pressure of earthenware pipes, table of, 222

Capped earthenware and stoneware pipes, 103
Cast-iron ball-and-socket joint, 40
,, ,, expansion joint, 168
,, ,, flange pipes, 33
,, ,, flanges, heavy oval, table of, 208
,, ,, ,, light oval, table of, 209
,, ,, ,, round, table of, 206
,, ,, pipes, 24
,, ,, ,, rule for thickness of, 48
,, ,, ,, ,, ,, weight of, 49
,, ,, ,, table of weight of, 202
,, ,, socket pipes, 25
Cement joint for socket pipes, 164
,, pipes, 122
City of London electric lighting station steam-pipe joint, 75
Clay joint for socket pipes, 160
Coal gas—floor of, in pipes, 13
Comparative weight of pipes, table of, 210
Composition pipes, 90
,, ,, table of weight of, 222
Condensation in long steam pipes, loss due to, 11
Coolgardie expansion joint, 174
Copper pipes, 51
,, ,, rule for weight of, 89
,, ,, table of weight of, 216
Corrosion in pipes, 135
Corrugated pipe joint—Wakefield's patent, 113

Deacon's expansion joint, 174
Deleterious effect of water in pipes, 135
Diameter of pipe required for water, 8
,, ,, steam pipes, 11
Discharge through pipes, 9
Doulton's "Opercular" pipes, 103
,, patent "Composite" joint, 111
,, ,, self-adjusting joint, 110
Drain pipes with tight-fitting sockets, 81
Duncan socket joint, 64

Eadie and Sons' flange joint, 80
Earthenware pipes, 98
,, ,, bursting pressure, table of, 222
,, ,, crushing of, table of, 223
,, ,, tensile strength of, 123
,, ,, thickness of, 124
Edinburgh socket pipe, 29

Expansion joints, 166
,, ,, balanced, 170
,, ,, Brown and Company, 170
,, ,, Coolgardie, 174
,, ,, Deacon's, 174
,, ,, hot water, 171
,, ,, ordinary cast-iron, 168
,, ,, steel, 169

Fire-clay pipes, 124
Fitzpatrick's patent drain pipe, 111
Flange pipes, 33
,, ,, cast-iron, 33
,, ,, joints for steel and wrought-iron pipes, 67
,, ,, ,, ,, india-rubber, 34
,, ,, ,, ,, gutta-percha, 36
,, ,, wrought-iron, 67
Flanges, heavy oval, table of, 208
,, light oval, table of, 209
,, round cast-iron, 206
Flow of gas in pipes, 13
,, ,, steam in pipes, 10
Friction of air, steam and gas in long pipes, table of, 185
,, ,, water in bends, 8
,, ,, ,, ,, pipes, 7
Froude's pipe scraping machine, 147

General remarks on cast-iron pipes, 45
,, ,, ,, wrought-iron pipes, 86
,, rules for pipes, 5
Glass-lined pipes, 136
,, pipes, 100
, ,, joints, 100
"Grooved" lead pipe joint, 94
Gutta-percha joint for pipes, 36

Hassel's patent safety pipe, 109
Head due to friction in air-pipes, 13
,, ,, ,, ,, bends, 8
,, ,, ,, ,, water pipes, 6
,, of water due to friction in bonds, 8
,, ,, ,, ,, ,, pipes, 6
Heating buildings with hot water, 14
,, rooms by hot water, 15
,, ,, ,, steam, 14
Heavy oval cast-iron flanges, table of, 208

Hot water, heating rooms by, 15
,, ,, pipe expansion joint, 171
How many pipes it will take to discharge the same quantity as one large pipe, 10
Howell's pipe joint, 74
Howell and Littler's box-flanged pipe coupling, 73

India-rubber pipe joint, 34
Inclination of pipes, usual, 9
Introduction, 1

Jackson's rule for velocity of water in pipes, 6
Joints, "Acme," 80
,, Aird's, 78
,, Ames and Crosta's, 116
,, "Albion," 79
,, Armstrong's hydraulic, 37
,, Botham's, 102
,, for cast-iron pipes, 25
,, for City of London electric lighting station, 75
,, Cliff's double seal, 126
,, for composition pipes, 92
,, Doulton's "composite," 111
,, ,, "opercular," 103
,, ,, self-adjusting, 110
,, Duncan socket, 64
,, Eadie and Son, 80
,, Edinburgh socket, 29
,, expansion, 166
,, Fitzpatrick's, 111
,, glass pipe, 100
,, "grooved," 94
,, Hassel's, 109
,, Howell's, 74
,, Howell and Littler's, 73
,, for lead pipes, 92
,, Lewis', 80
,, Liverpool socket, 29
,, Lloyd and Lloyd, "Albion," 79
,, Macdougall's ball-and-socket, 83
,, Metropolitan electric lighting station, 75
,, Melling's, 96
,, "Opercular," 103
,, Paisley socket, 30
,, "Paragon," 108
,, Piggott's socket, 65
,, Riley's, 65

Joints, Risdon ball-and-socket, 84
,, for steel pipes, 63
,, Stewart Menzies', 78
,, Sykes' new patent, 103
,, ,, patent screw, 105
,, Toronto ball-and-socket, 83
,, Tylor's patent "grooved," 94
,, universal india-rubber (Richardson's patent), 38
,, Vyrnwy works' socket, 30
,, ,, ,, ball-and-socket, 82
,, Wakefield corrugated, 113
,, Willans' steam flange, 72
,, wood pipe, 19
,, Wood's cast-iron ball-and-socket, 42
,, ,, socket, 31
,, wrought-iron pipe, 60
,, ,, ,, tight-fitting socket, 81
Jones' improved flange-pipe joint, 38

Kennedy's scraping machine, 144

Lead joints, table of, 197
,, pipes, 90
,, ,, thickness of, 97
,, ,, weight of, rules for, 97
Laying of pipes, 160
,, mains under water, 197
Length of pipe required for heating rooms with hot water, 14
,, ,, ,, ,, ,, ,, steam, 14
Lewis' patent "Acme" joint, 80
Light oval cast-iron flanges, table of, 209
Liverpool socket pipes, 29
Loss due to condensation in long steam pipes, 11
Loose sockets, weight of, 215
Lloyd and Lloyd's "Albion" pipe joint, 79

Macdougall, wrought-iron ball-and-socket joint, 83
Machines for scraping pipes, 142
,, ,, testing earthenware pipes, 159
Mains under water, laying, 197
Mather and Platt's (Brierly and Melling's) lead pipe joint, 96
Melling's lead pipe joint, 96
Metropolitan electric lighting station steam-pipe joint, 75

Number of pipes in a pile, 47
,, ,, ,, triangular pile, 47

Oil-line pipes, 62
"Opercular" pipes (Doulton's), 103
Ordinary expansion joints, 168
Oval cast-iron flanges, table of heavy, 208
,, ,, ,, ,, light, 209

Paisley socket pipes, 30
Paper pipes, 197
"Paragon" pipe joint, 108
Petroleum pipe-line, 62
Phelps' metal, 163
Piggott's steel socket joint, 65
Pipes, cast-iron, 24
  ,, ,, ,, flanges, 33
  ,, ,, ,, socket, 25
  ,, composition, 90
  ,, diameter of, required, 8
  ,, ,, ,, steam, 11
  ,, discharge of water through, 9
  ,, flow of steam in, 10
  ,, general remarks on cast-iron pipes, 45
  ,, ,, ,, ,, wrought-iron-pipes, 96
  ,, head due to friction in air, 13
  ,, joints for cast-iron pipes, 25
  ,, ,, ,, composition pipes, 92
  ,, ,, ,, earthenware pipes, 101
  ,, ,, ,, lead pipes, 92
  ,, ,, ,, steel pipes, 60
  ,, ,, ,, wood pipes, 19
  ,, ,, ,, wrought-iron pipes, 60
  ,, laying, 160
  ,, line, petroleum, 62
  ,, paper, 197
  ,, scraping machines, 142
  ,, velocity of air in, 12
  ,, ,, ,, steam in, 10
  ,, ,, ,, water in, 6
Place's patent lock-joint, 117

Quantity of air to be heated in rooms, 14
  ,, ,, water discharged through pipes, 9

Remarks on cast-iron pipes, 45
  ,, ,, earthenware, stoneware, stone, and glass pipes, 123
  ,, ,, wrought-iron pipes, 86
Richardson's patent universal india-rubber joint, 38
Riley's stamped steel socket joint, 84

Risdon, wrought-iron ball-and-socket joint, 84
Rockwood's flanged joint, 71
Rooms, heating by hot water, 15
,, ,, ,, steam, 14
Rotary pipe cramping machine, 150
Round cast-iron flanges, table of, 206
Rules for thickness of cast-iron pipes, 48
,, ,, ,, copper pipes, 89
,, ,, ,, earthenware pipes, 124
,, ,, ,, lead pipes, 97
,, ,, ,, steel pipes, 88
,, ,, ,, wrought-iron pipes, 87
,, weight of cast-iron pipes, 49
,, ,, ,, steel pipes, 88
,, ,, ,, wrought-iron pipes, 88
,, pipes, general, 5

Scraping machines, 142
,, ,, American, 150
,, ,, Appold's, 142
,, ,, Froude's, 147
,, ,, Kennedy's, 144
,, ,, Rotary, 150
,, ,, Tylor's, 150
,, ,, summary of, water-mains, 152
Screwed joints for wrought-iron and steel pipes, 60
Scrapers for pipes, 142
Sewer pipes, 119
Sheffield water-works, 17
Sidero cement pipes, 122
Socket pipes, 25
,, ,, cast-iron, 25
,, ,, Edinburgh, 29
,, ,, Liverpool, 29
,, ,, not turned, table of, 52
,, ,, turned, table of, 26
,, ,, Vyrnwy, 30
,, ,, steel, 63
,, ,, wrought-iron, 63
Solid drawn copper pipes, table of weights of, 214
Stanford pipe joint, 107
Steam pipes, diameter of, 11
,, ,, flow of steam in, 10
,, ,, heating rooms by, 14
,, ,, loss due to condensation in, 11
Steel expansion joints, 169
,, pipes, 51

Steel pipes, thickness of, 88
,, steam pipes, table of thickness of, 87
,, socket pipes, 63
,, sockets, weight of, 213
Stewart and Menzies' pipe joint, 78
Stone pipes, 98
Stoneware pipes, 98
,, ,, thickness of, 124
,, ,, taper, 125
Summary of scraping water-mains, 152
Sutton's flush-joint pipe, 119
Sykes' new patent pipe joint, 103
,, patent screw joint, 105

Table I. Friction of air, steam, and gas in long pipes, 185
,, II. ,, ,, water in pipes 100 feet length, 187
,, III. Flow of steam through pipes, 196
,, IV. Branch pipes of equal area to the main pipe, 198
,, V. Weight of cast-iron pipes, 202
,, VI. Socket-pipes (not turned and bored), 204
,, VII. ,, (turned and bored), 205
,, VIII. Proportions of cast-iron flanges on cast-iron pipes, 206
,, IX. ,, ,, flanges for wrought-iron pipes, 206
,, X. ,, ,, heavy oval flanges, 208
,, XI. ,, ,, light oval flanges, 209
,, XII. Comparative weight of pipes per lineal foot, 210
,, XIII. Weight of solid drawn wrought-iron pipes, 211
,, XIV. ,, ,, ,, ,, ,, 211
,, XV. ,, ,, large welded wrought-iron pipes, 212
,, XVI. ,, ,, riveted wrought-iron pipes, 212
,, XVII. ,, ,, angle-iron flange rings riveted on pipes, 213
,, XVIII. ,, ,, steel sockets riveted on pipes, 213
,, XIX. ,, ,, solid drawn copper tubes, 214
,, XX. ,, ,, loose sockets, 215
,, XXI. Thickness of steel steam pipes for varying pressures, 215
,, XXII. Weight of copper tubes per foot run, 216
,, XXIII. ,, ,, brass tubes per foot run, 216
,, XXIV. ,, ,, ,, ,, ,, ,, 217
,, XXV. ,, ,, lead pipes per length, 217
,, XXVI. Thickness of pipe required, etc., 218
,, XXVII. Weight of lead pipes required for a given head of water, 221
,, XXVIII. ,, ,, per lineal foot, 221
,, XXIX. ,, ,, and patent composition gas pipes, 222
,, XXX. Bursting pressure and tensile strength of earthenware pipes, 222
,, XXXI. Experiments on the crushing of earthenware pipes, 223

Table XXXII. Internal diameter, length when laid, thickness and depth of socket of stoneware, earthenware, and fire-clay pipes, 224
,, XXXIII. Square of numbers, 224
,, XXXIV. Square root of numbers, 227
,, XXXV. Fifth root of numbers, 229
,, XXXVI. ,, ,, ,, 231
,, XXXVII. Square root of the fifth powers, 233
Taper stoneware pipe, 124
Tensile strength of earthenware pipes, 123
Testing machine for crushing strength of sanitary pipes, 159
,, ,, ,, large pipes, 155
,, ,, ,, small pipes, 153
,, ,, ,, tensile strength of sanitary pipes, 159
,, pipes, 153
Thickness of cast-iron pipes, rule for, 48
,, ,, earthenware pipes, 124
,, ,, lead pipes, 97
,, ,, steel pipes, 88
,, ,, steel steam pipes, 88
,, ,, stoneware pipes, 124
,, ,, wrought-iron pipes, 88
Toronto ball-and-socket joint, 83
Tubes, brass, weight of, 89
,, copper, weight of, 89
Tylor's patent "grooved" lead pipe joint, 94
,, pipe-scraping machine, 150

Underground pipes, 2
Universal india-rubber joint, Richardson's patent, 38
Usual inclination of pipes, 9

Velocity of air in pipes, 12
,, ,, steam in pipes, 10
,, ,, water in pipes, 9
Vyrnwy works, Liverpool, socket joint, 30

Wakefield's drain pipe joint, 113
Walker's cast-iron ball-and-socket joint, 41
Water gas, flow of, in pipes, 13
Weight of angle-iron rings riveted to pipes, table of, 213
,, ,, brass tubes, rule for, 89
,, ,, ,, ,, table of, 216
,, ,, cast-iron pipes, rule for, 49
,, ,, ,, ,, table of, 202
,, ,, composition pipes, table of, 222
,, ,, copper tubes, rule for, 89
,, ,, ,, ,, table of, 216

Weight of lead pipes, rule for, 97
,, ,, ,, ,, table of, 217
,, ,, riveted wrought-iron pipes, table of, 212
,, ,, steel pipes, rule for, 88
,, ,, wrought-iron pipes, rule for, 88
,, ,, ,, ,, table of, 211
Willans' steam flange joint, 72
Wood pipes, 16
,, pipe joints, 19
Wood's cast-iron ball-and-socket joint, 42
,, socket pipe, 31
Wrought-iron ball-and-socket joints, 82
,, drain pipes, 81
,, pipes, 51
,, socket-pipes, 63
Wychoff wood pipes, 22

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